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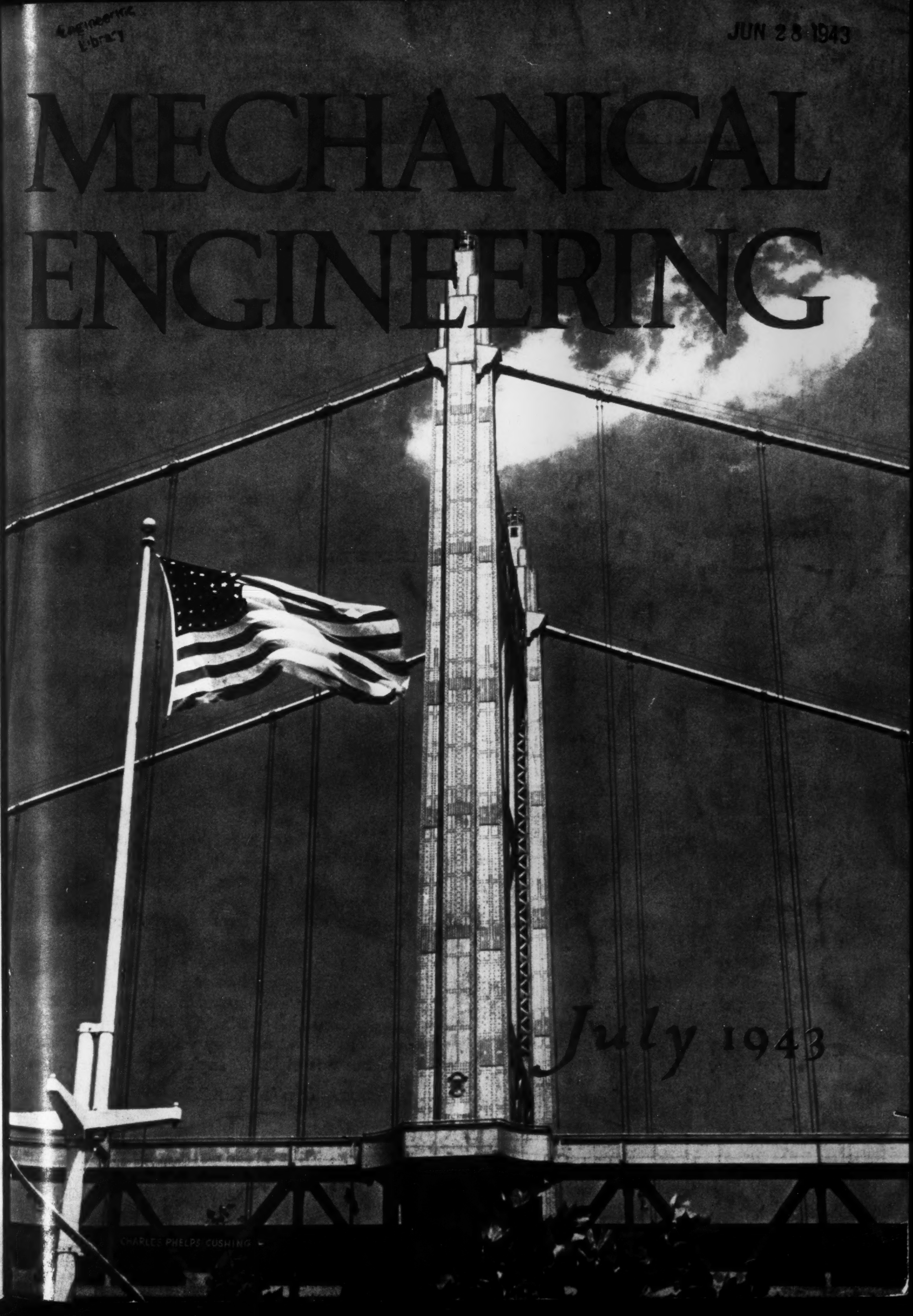
MECHANICAL ENGINEERING



July 1943

CHARLES PHELPS CUSHING

★ WAR WORK *Begins at 40*

For these B & W BOILERS

At the ripe age of 40, five of these central-station B&W boilers of 1902 were recently drafted for work in a Southern war plant, thereby saving critical materials that would have been required in the construction of new boilers for this service.

A lot of steam flowed from their charcoal-iron, hammer-welded tubes since they were first placed on the line, yet, when they were given a careful "physical" this year by the inspectors, they were pronounced hale and hearty, ready for induction into war service.

This fact testifies not only to the soundness of their design, but to the excellence of the materials and workmanship that entered into their construction 'way back in 1902—always a matter of pride with the manufacturers of B&W boilers. It also testifies that the boilers must have received excellent care from their operators.

And these are only five of many B&W boilers, that, after long and useful lives in other fields, are being drafted for re-installation in war industries, where, incidentally, they will continue to receive the benefits of B&W engineering and service.

"VICTORY is a job for steam . . . and steam is a job for B&W."

BABCOCK & WILCOX
THE BABCOCK & WILCOX COMPANY
85 LIBERTY STREET, NEW YORK, N. Y.

BABCOCK, WILCOX & COMPANY, 1867
THE BABCOCK & WILCOX COMPANY, 1881

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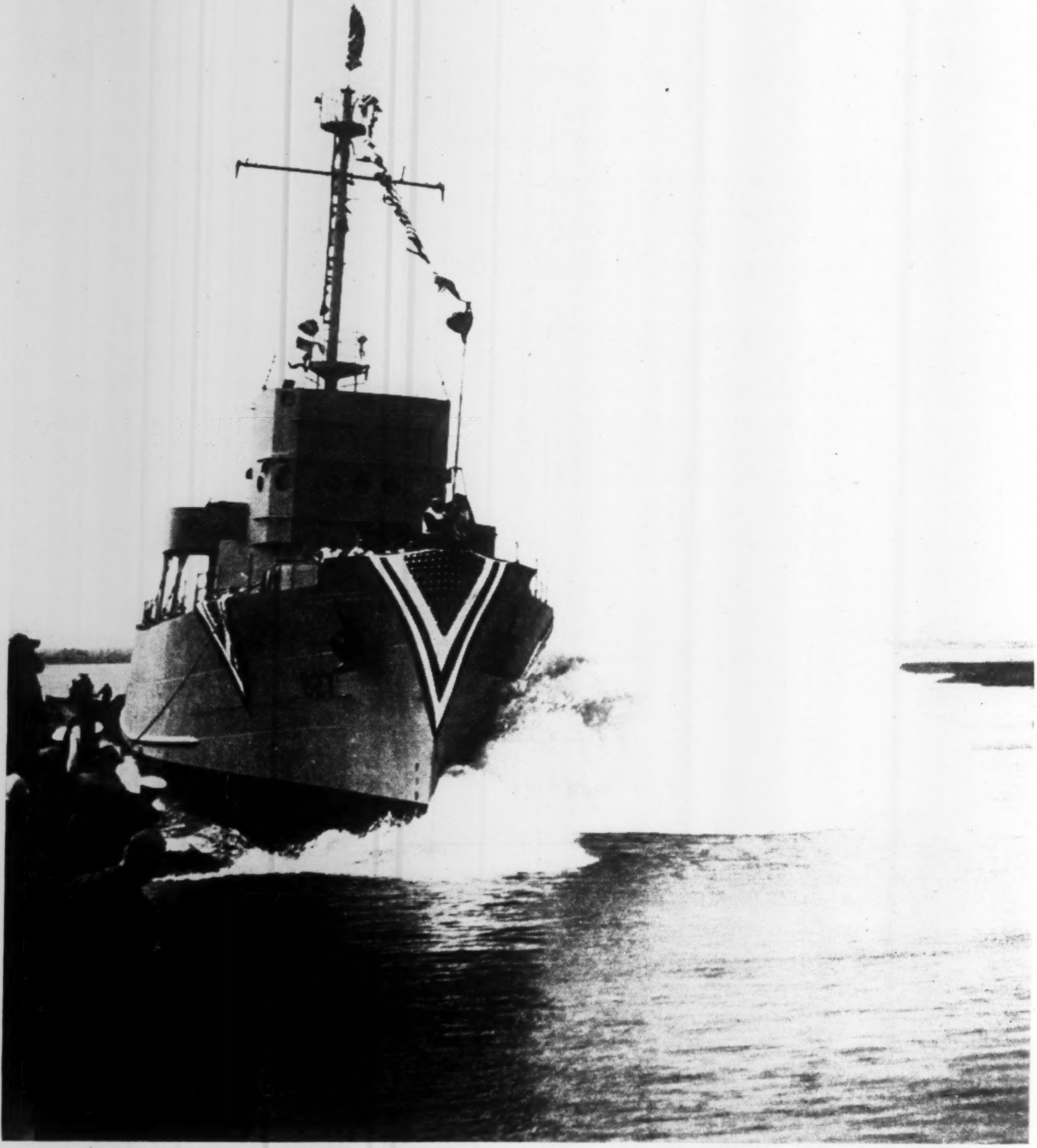


Official U. S. Navy Photograph

The U. S. Navy's Latest Antisubmarine Weapon,—the New Patrol Craft Escort

(Designed for heavy convoy duty in northern waters, these ships are powerfully armed with dual-purpose and antiaircraft guns and well equipped with depth charges. The PCE shown here was recently launched at Chicago, Ill.)

VOLUME 65
No. 7

MECHANICAL ENGINEERING

JULY
1943

GEORGE A. STETSON, *Editor*

Biomechanics in Airplane Design

THE growing importance of the airplane in warfare is one of the outstanding developments of this age. Every military angle of the use of airplanes is being explored rapidly and with great thoroughness. As the number of planes increases with all-out production we are accumulating evidence that both by themselves and in conjunction with other fighting units airplanes are essential to victory. This fact lays a heavy responsibility on designers and producers to maintain a steady flow of vast quantities of planes, engines, and equipment. That success is being achieved in this important task reflects great credit on designers, manufacturers, and engineers, as well as all others engaged in this vital enterprise.

Airplanes are useless without crews and crews are useless without pilots. Our enormous aviation training program is taking the finest young men of the nation to make up the personnel needed for the thousands of planes that are being produced. Physical and mental qualifications are high and the pool of young men from which these crews are chosen is not inexhaustible. The development of trainees into competent pilots takes time. Every hour of training and of flying and military experience adds greatly to the value of these men to the nation and the cause of the United Nations. The hazards of war are so great in themselves that every effort must be exerted to make sure that under all conditions of training and service the lives of pilots and airplane crews are safeguarded as greatly as is consistent with the full performance of their heroic tasks.

So well have designers and manufacturers of airplanes and airplane engines done their work that accidents from mechanical and structural failures had almost disappeared from civil aviation before the war. Presumably, the percentage of such accidents has continued to decrease and will continue to do so after the war. But whether from enemy action in war, from mechanical failures in peacetime, from human errors in training, or in experienced flying, airplane crashes are bound to occur, and when they do the pilots, crews, and passengers should be assured that designers, builders, and operators have co-operated to see to it that every reasonable precaution has been taken to minimize the severity of the crash. It is at this point that intelligent safety consciousness becomes important.

Intelligent safety consciousness of all persons concerned with airplanes, and particularly their cockpits, covers several basic principles and many details of design. In general, all of these can be lumped together under the single principle of considering the aircraft and its pilot (and to some extent other occupants) together, as one would consider a shipping crate for any fragile article, with the difference that the pilots (and other occupants) must have freedom of movement essential to the functions they have to perform. To avoid fatal or serious injuries to the head, back, legs, and ankles of the pilot, the designer must study the human body as he studies the structure and materials of the plane itself. His design should be arranged so that the shocks of the crash expend their major force on the airplane structure and only reach the human body with reduced intensity and in such a manner that the body can withstand them. To design an airplane cockpit, for example, along the lines suggested calls for the intelligent application of the principles of biomechanics of the human body, and hence the closest co-operation between the great professions of orthopedic surgery and engineering is demanded.

To the credit of both professions it may be said that a start is being made on a combined attack on this important task of attempting to save lives and diminish injuries to pilots that result from airplane crashes. What aeromedicine has already accomplished, particularly in high-altitude flying, is fairly well known. Because of wartime restrictions the work that is being carried on to eliminate as many as possible of the cockpit projections that result in head injuries in crashes and to improve safety devices and design features likely to cause back and leg injuries are less well known. But the complete job of considering from a safety point of view every feature of the human body in respect to the airplane structure in which it is carried is yet to be done.

Fundamentally, the responsibility for the complete job rests on the engineer—the airplane designer. Doctors and orthopedic surgeons can assist by pointing out to engineers the weak and strong features of the body. The task of safeguarding the weak elements and taking advantage of the strong belongs to the engineer who must base his designs on the principles of biomechanics. Fortunately, this knowledge is available.

Several times during the last decade attention has been directed in these pages to examples of co-operation between engineers and orthopedic surgeons in the field of biomechanics. Today, and in the future, this co-operation must be extended to encompass the design of airplanes and particularly airplane cockpits for reasons already advanced. The task is a long one and some of it may have to be delayed because changes in design under wartime conditions are difficult to make. Eventually, however, working with orthopedic surgeons along the principles of biomechanics, airplane designers will become safety-conscious in this important and fertile field. It has been competently estimated that at least 25 per cent of the fatalities could have been avoided if proper attention had been given to the design of planes and cockpits and to pilot training. Even a single life so saved, with no inconvenience to the pilot in the performance of his functions, would justify the effort. Engineers cannot begin too soon to apply the principles of biomechanics to the safety features of airplane design.

Strategic Bombing

STRATEGIC bombing, which the air forces of the United Nations are carrying out so successfully in Europe and the Mediterranean area, was explained in a lucid and interesting manner by General E. P. Sorensen, assistant chief, Army Air Force Staff Intelligence, War Department, Washington, D. C., in a speech delivered at the 1943 Semi-Annual Meeting of The American Society of Mechanical Engineers held in Los Angeles on June 16. Coming so closely in the wake of victories in Tunisia, Pantelleria, and Lampedusa, and the tremendous air raids over Europe in which carefully selected industrial targets are being relentlessly destroyed, the speech had a timeliness that excited unusual interest.

General Sorensen's speech also served as an effective follow-up of speeches that Colonel James L. Walsh has been making throughout the length and breadth of the land for more than a year, in which he has been driving home to engineers in industrial centers the fact that air power has no natural coast line at which naval engagements or surface invasions must begin, and the further fact that, in such a war as we are now fighting, the science of logistics—supply of the armed forces—is important. Failure on the production front may come through inability to produce and transport in sufficient quantity, and enemy action against production centers and supply lines may seriously hamper efforts in the field.

Recalling a paper written by Mr. Churchill in 1917 which said, in effect, that "nothing that we know about warfare can lead us to believe that bombing for terror alone can cause such a morale collapse as to force a major nation to sue for peace," General Sorensen pointed out that the failure of the Germans to win the Battle of Britain had proved this point. Mr. Churchill's further contention that "air power must single out and attack transportation, factories, and other enemy installations upon which the enemy war-making ability depends" is being demonstrated by the Allies at the present time.

Germany, General Sorensen pointed out, although successful in the use of air power in the early days of the war when it was used to attack enemy surface forces at and near the line of contact, to transport men and equipment, and to defend their own forces and territory, "did not visualize the singling out of industrial units as being a refined process. . . . Instead of visualizing the airplane and its bomb load as being finite quantities, she seemed to consider them as being capable of covering England with a solid blanket of fire and explosives, thereby insuring the destruction of all British industrial units."

On the other hand, General Sorensen continued, "Efficiency expressed in the military maxim 'economy of effort' is an epitome of the air concept upon which we have based all of our efforts, and this is best attained in strategic bombing by scientific target selection and precise placement of bombs where they will do the most real damage."

Reviewing the several phases of strategic bombing which at first appear aimless and nonspectacular and which cause little or no inconvenience to the armies in the field because of the accumulation of matériel built up previously, General Sorensen passed on to the last phase which starts "when we have completed the initial destruction of the selected vitals and have started the cleaning-up process on items overlooked. . . . The invasion should start," he said, "when to delay longer would waste effort, but when its cost has been reduced to a minimum."

Certain special features of the "American concept of Air Force, and particularly of one idea of strategic bombing, which tend to lift Air Power from the depths of Axis brutality," were summarized by General Sorensen as follows:

> In the first place, we hope and fully expect to prevent most of the enormous losses which would be suffered on our side without this bombing, a saving beside which the most severe air losses will be infinitesimal. Next, the result of precision is efficiency measured in economy of effort, allowing the forces available to accomplish the task with minimum waste and in the shortest possible time.
>
> Another less tangible consideration, but one which cannot be ignored, is the postwar attitude of the nations toward each other. Bombing at its best cannot fail to cause some extraneous destruction and must certainly make the war and its hates very real to victim populations. Carelessness on our part would intensify and spread those hates which would be stumbling blocks to international peace for years after the actual fighting is over. Precision will hasten the time of new understanding.
>
> Finally, we must recognize that postwar economy is intimately related to the manner in which bombing targets are selected and attacked. Due to the fact that modern communications have tied all peoples of the world as close to each other as were the original colonies from which this nation was formed, the standard of living of one nation must hereafter be definitely affected by that of any other. There must be a leveling off.
>
> In order to prevent a serious reduction in our own standard, we must assist in the rebuilding of every other nation, enemy or ally. Therefore, aside from the necessity for economy of effort in winning the war, we have a very potent urge to defeat the enemy without causing any but the most unavoidable amount of extraneous destruction.

It is these phases and objectives that engineers, whose normal activities are constructive and on whom the burden of postwar reconstruction will fall, will find of the greatest significance.

Cleveland Sets an Example

THE public services being rendered by the recently organized Fuels Division of the Cleveland Engineering Society are briefly described in a short article by James H. Herron that appears in this issue.

This quick response to one of the pressing needs of the times is a demonstration of alertness on the part of Cleveland engineers. The instant success of the division was shown by the number of meetings and the attendance at them as well as the number of agencies in the community that sought the aid and advice of the division.

As Mr. Herron well says, "Its progress presents a challenge to similar groups." Cleveland has set an example for engineers everywhere.

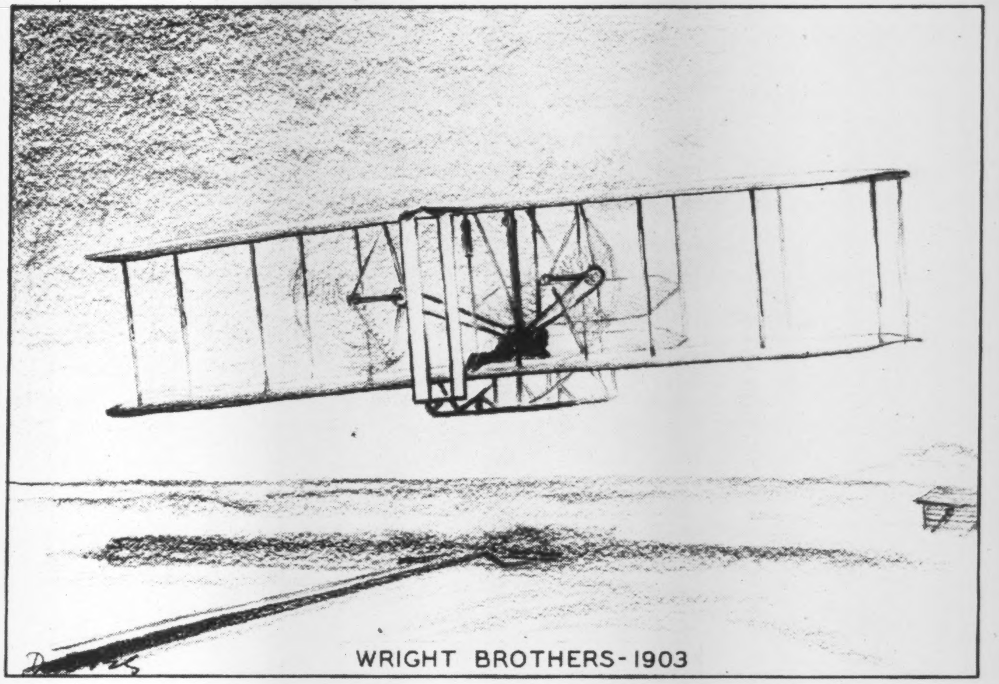


FIG. 1

AIR TRANSPORTS—PAST *and* FUTURE

By W. W. DAVIES

RESEARCH ENGINEER, UNITED AIR LINES TRANSPORT CORPORATION

WHAT is to be the future of air transportation? Those most closely associated with the industry are firmly convinced that the airplane will hold a place of equal rank with other transportation forms, not supplanting them, but rather augmenting them in service to mankind. This augurs well for a bright and healthy future.

The success of air transportation will depend to a very major extent upon the flying equipment available. It is the purpose of this paper to present, in small measure, the background and past development of the airplane, together with a possibility as to future characteristics and operation.

TECHNICAL HISTORY

AIRCRAFT

It is beyond the scope of this discussion to give complete and detailed analyses of the many types of heavier-than-air planes developed and used for flight, since the early days of the Wright Brothers. However, the following briefs of major design features, for a few which were successful, will help to portray the background and develop some of the trends.

Wright Brothers—1903. The first airplane to achieve full flight, Fig. 1, was a biplane type without fuselage which utilized front elevator and twin rear rudder. Lateral control was obtained by warping the wings, and runners or skids were used for landing gear. Two pusher-type propellers were incorporated. The principal particulars were gross weight, 750 lb; wing span, 40 ft; one 4-cylinder engine of 12 bhp; speed 30 mph max; capacity, one.

Santos Dumont—1906. The first official flight in France was that of Santos Dumont flying a biplane-type craft with front elevators and rudder, having extreme wing dihedral. One pusher-type propeller was used. Dumont is claimed to have been the first to take off with wheel gear in place of catapult or rail. The principal particulars were, gross weight, 645 lb; span, 41.8 ft; one 8-cylinder 50-bhp engine; speed, 25 mph max; capacity, one. Later, Dumont designed what is classed as the smallest airplane, with a gross weight of 330 lb. It incorporated a 17 to 25 bhp engine and was supposed to have attained speeds up to 65 mph. A three-wheel gear was used.

Maurice Farman—1909. Farman's machine was a biplane craft using a double tail aft with the rudder between. Horizontal elevators were used in front and wing tips were warped for lateral control. One pusher-type propeller was fitted. The particulars of this craft were gross weight, 990 lb; span, 32.8 ft; one 8-cylinder engine; speed, 50 mph max; capacity, one.

Louis Bleriot—1909 (Model IX). This was a monoplane type incorporating fixed wings with ailerons and vertical rudder and horizontal elevators in rear. A view is given in Fig. 2. Bleriot also used three-wheel landing gear and tractor-type propeller.

Contributed by the Aviation Division and presented at the Spring Meeting, Davenport, Iowa, April 26–28, 1943, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

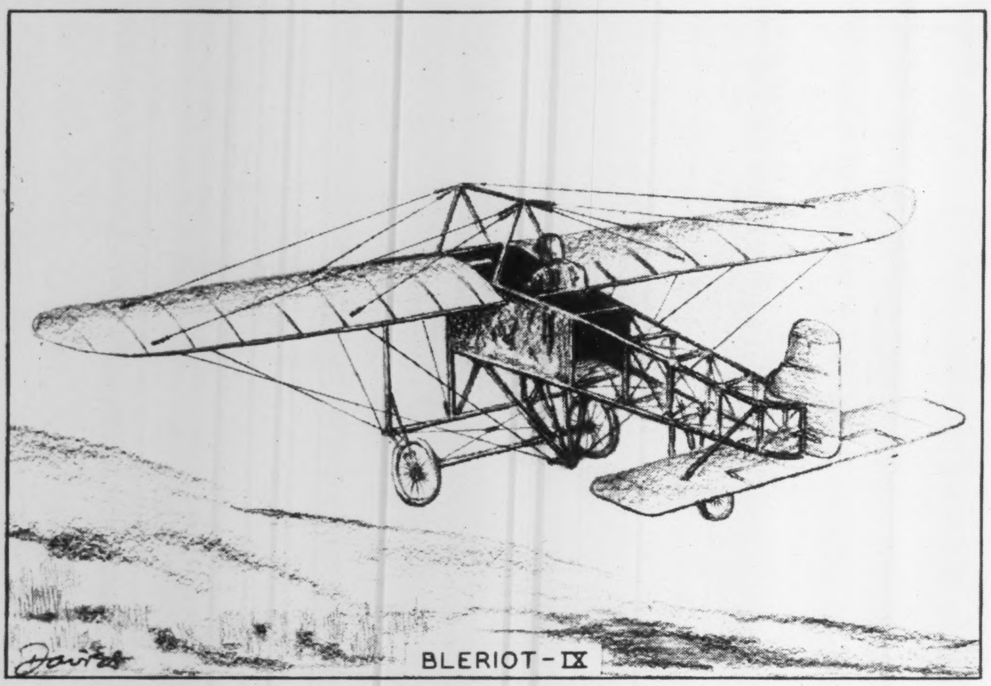


FIG. 2 BLERIOT-IX

The principal particulars were gross weight, 1234 lb; span, 32.75 ft; one 16-cylinder 50-bhp engine; speed, 46 mph max; capacity, one.

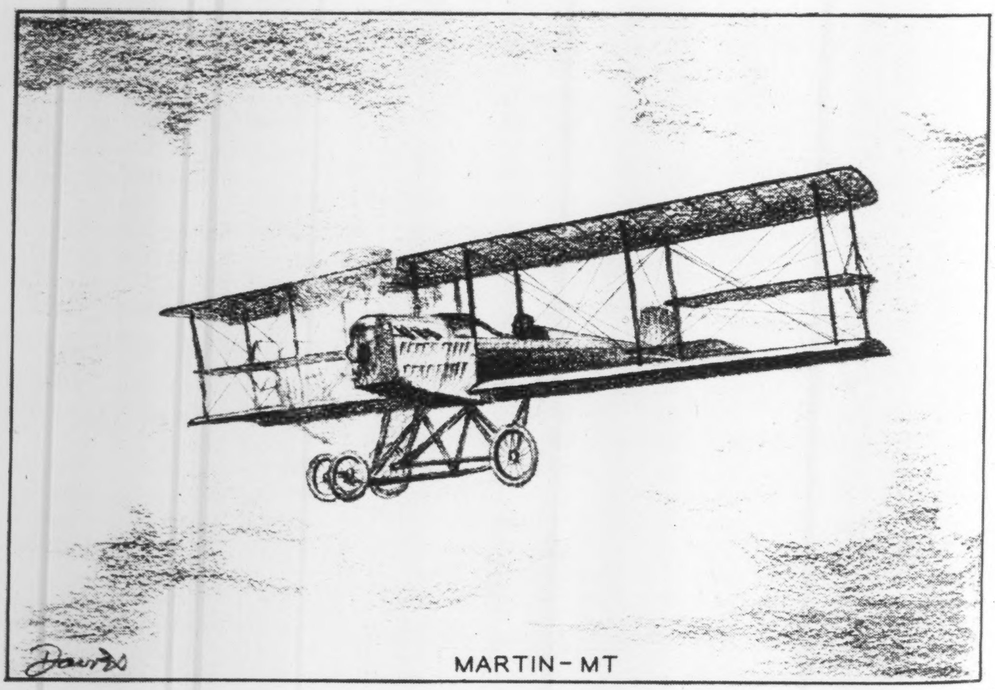
Curtiss—1909. The first Curtiss designed plane appeared in 1909 and was known as the *June Bug*. This was also a biplane using a horizontal rudder in front, a box tail in the rear, and ailerons were also incorporated. Again, a pusher-type propeller and three-wheel landing gear were employed. The principal particulars of this type were gross weight, 660 lb; span, 36.25 ft; one 8-cylinder 25-bhp engine; speed, 39 mph max; capacity, one.

The Wright Brothers designed another biplane in 1909, for Army tests. This craft could carry two people at a gross weight of 1157 lb. It again was a two-propeller pusher type, with a 27-bhp engine giving it a maximum speed of approximately 32 mph.

Albatross—1912. This airplane was a German two seater biplane design using landing gear consisting of two pairs of wheels, with skids both forward and aft. Elevator and rudder were both in the rear; a tractor-type propeller was used. The principal particulars of this type were, gross weight 1058 lb; span, 43.6 ft; one 4-cylinder 100-bhp engine; cruising speed 56 mph; capacity, two.

During the first world war, all efforts were concentrated upon the development of satisfactory warplanes such as the De Havilland DH-4, Nieuport, Handley-Page, Loening, and Burgess flying boat. One of the more familiar types of this period was the Curtiss JN4, the *Jenny*. This was a biplane trainer

FIG. 3 MARTIN-MT



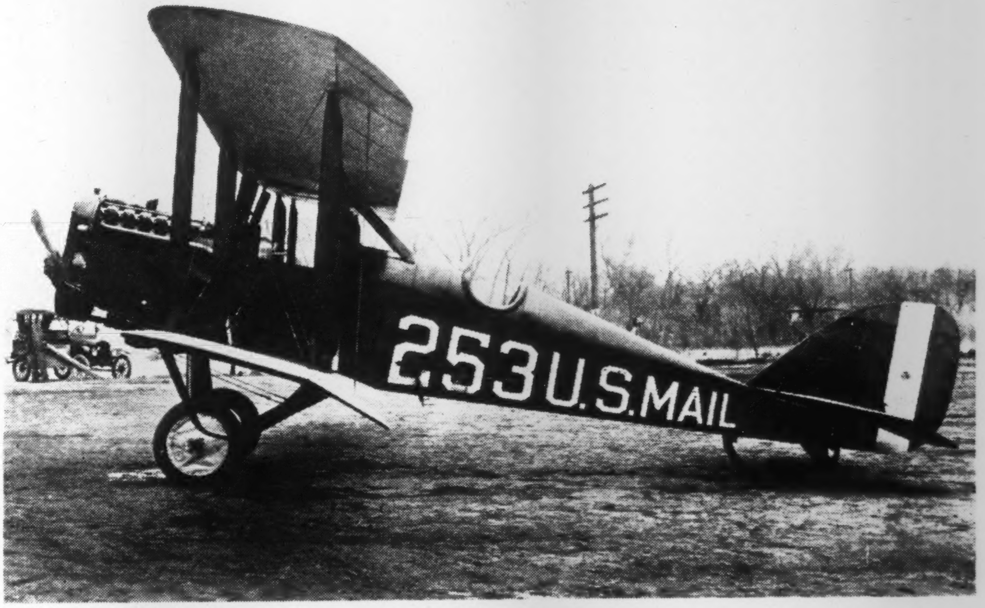


FIG. 5 DEHAVILLAND DH-4 CONVERTED

with tractor propeller. The use of regular ailerons on the wings and rudder and elevators on the tail had now become general. Landing gear consisted of two main wheels with tail skid. The principal features were gross weight, 2130 lb; span, 43.6 ft; one 8-cylinder Curtiss Ox-5, 90-bhp engine; speed, 75 mph max; capacity, two.

Martin Bomber—1918. The Martin bomber, Fig. 3, was another interesting development from that war. It was of biplane design with twin tail and four-wheel main gear and tail skid. This was a large two-engine design, the main particulars of which were, gross weight, 9600 lb; span, 71.5 ft; two Liberty engines of 400 bhp each; cruising speed approximately 100 mph.

Curtiss NC-4—1919. This constituted one of the more familiar seaplane developments. It carried a crew of five for approximately 1500 miles. The main particulars were gross weight, 28,000 lb; span 126 ft; four Liberty engines of 420 bhp each; speed, 90 mph max.

After the war, came the first real development of aircraft for commercial use in the United States. The majority of those which made air-mail history were of the biplane tractor-propeller type. The general characteristics of a few of these are as follows:

Curtiss Pigeon—1920. First plane designed exclusively for mail service, Fig. 4; capable of 725-mile range; gross weight, 4900 lb; span, 41.9 ft; one Liberty engine of 400 bhp; speed, 120 mph; capacity, pilot and 600 to 800 lb cargo.

De Havilland DH4 (converted)—1922. Fig. 5 shows converted DeHavilland; gross weight, 3472 lb; span, 42 ft; one Liberty engine of 400 bhp; cruising speed, 100 mph; capacity, pilot and 400 lb cargo.

Douglas M-2—1926. Gross weight, 4965 lb; span, 39.6 ft; one Liberty engine of 400 bhp; cruising speed 110 mph; capacity, pilot and 800 lb cargo.

Boeing 40-B—1927. The Boeing 40-B, shown in Fig. 6, had a gross weight of 6078 lb; span, 44.2 ft; one P&W engine, 525 bhp; cruising speed, 115 mph; capacity, pilot, 1500-lb cargo, and 2 to 4 passengers.

Then in the ensuing years, came rapidly the development of air transportation as a definite means of travel. The Boeing 80-A's, Fig. 7; the Ford Trimotors, Fig. 8; Curtiss Condors,

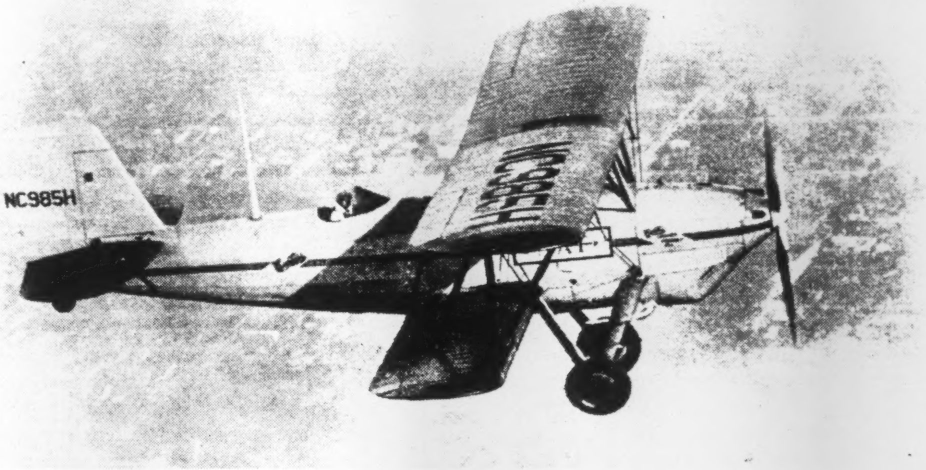


FIG. 4 CURTISS CARRIER PIGEON

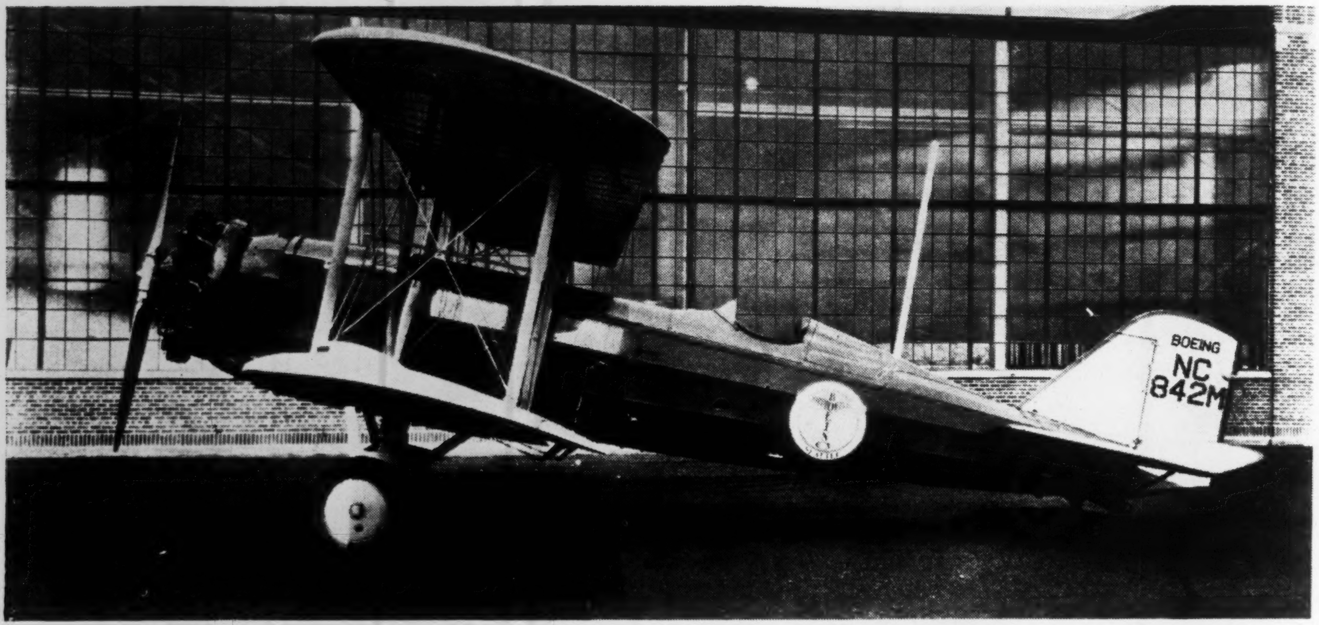


FIG. 6 BOEING 40-B-4

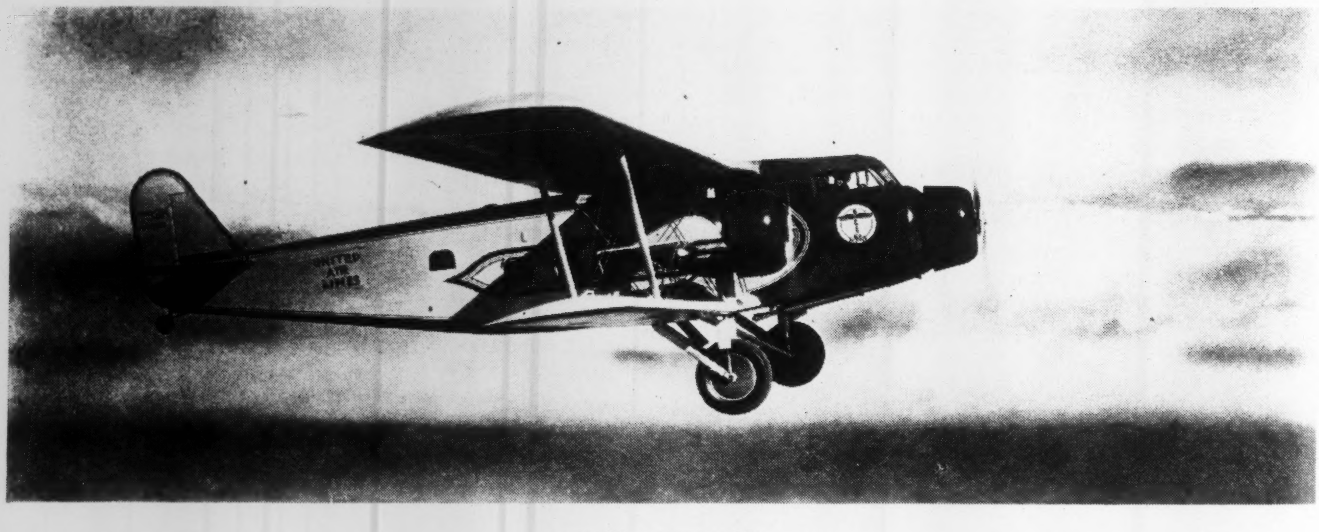


FIG. 7 BOEING 80-A

Monomails; and Boeing 247-D's, Fig. 9; up to the familiar Douglas DC-3's, Fig. 10, which are so widely used today.

TRENDS OF PERFORMANCE AND DESIGN FEATURES

This is only a brief glimpse of the history of the airplane but it will tend to illustrate the progress which has been made. If it were possible to analyze mathematically this progression, a curve could be drawn which would give a visual indication of the airplane's development. Obviously, this is impractical, but such a type of curve can be drawn for individual characteristics of all craft, which will prove to be expressive at least of the possibilities. Figs. 11 to 20, inclusive, are such curves showing the trend of major performance and design features. They should not be classed as being fully quantitative.

Data for plotting these curves were obtained from the generally accepted authorities. It must be appreciated that the greater portion of the data available from the early years are approximate but yet sufficiently accurate to establish the curves. All airplanes, of course, have not been plotted, but generally speaking, most commercial transports or those capable of being so used have been included where data were available. During the early years when there was no differentiation between aircraft uses, data from all types were used, including some foreign models but only United States commercial-transport data were plotted from 1930.

Fig. 11 indicates the rapid trend in the late years toward larger aircraft. The upper limit shown on the curve has already been exceeded by a considerable margin. However, it should not be interpreted that only large gross-weight airplanes will be used in the future as the size craft employed will be determined on the basis of the service to be performed. It is altogether probable that the curve will "fan out," indicating a lower and upper range for commercial transports.

Fig. 12 illustrates the past trend of useful-load ratio. There is a wide spread of points shown, but, in the original plot, by condensing the left-hand scale, it was possible to indicate the trend. The trend in later years appears to be in the opposite direction to that desired and this is quite correct. It should be remembered that in the early '29's and '30's the passenger transport was just beginning to appear and more attention was paid to getting a substantial load on board. Later, however, with increased speeds requiring greater structures and passenger-

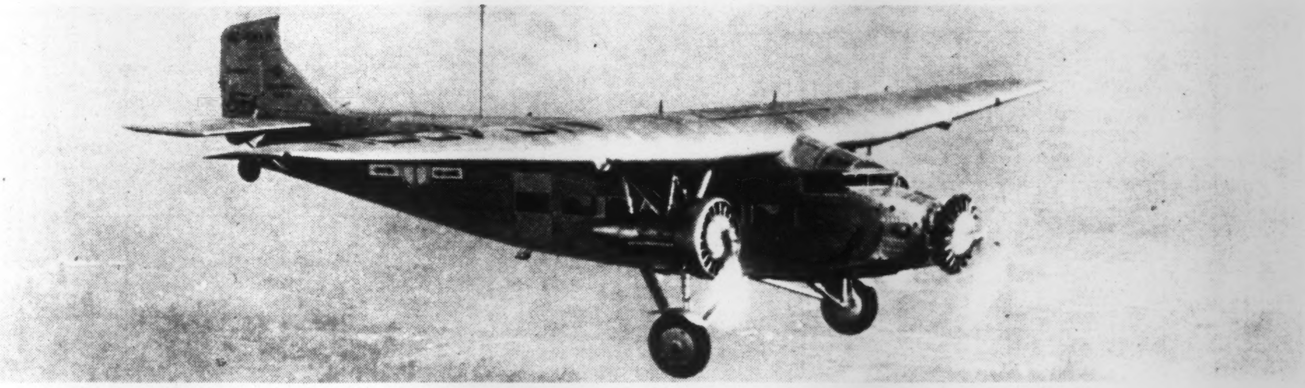


FIG. 8 FORD TRIMOTOR—5-AT-C

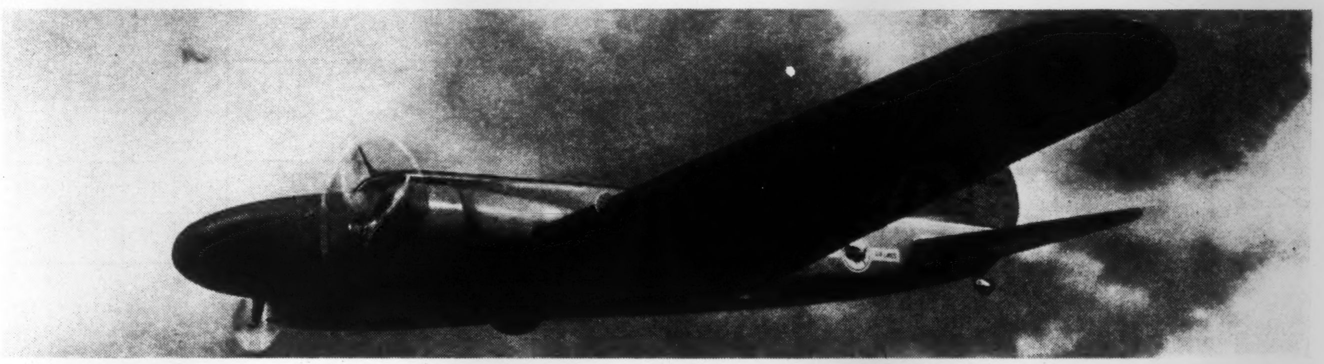


FIG. 9 BOEING 247-D

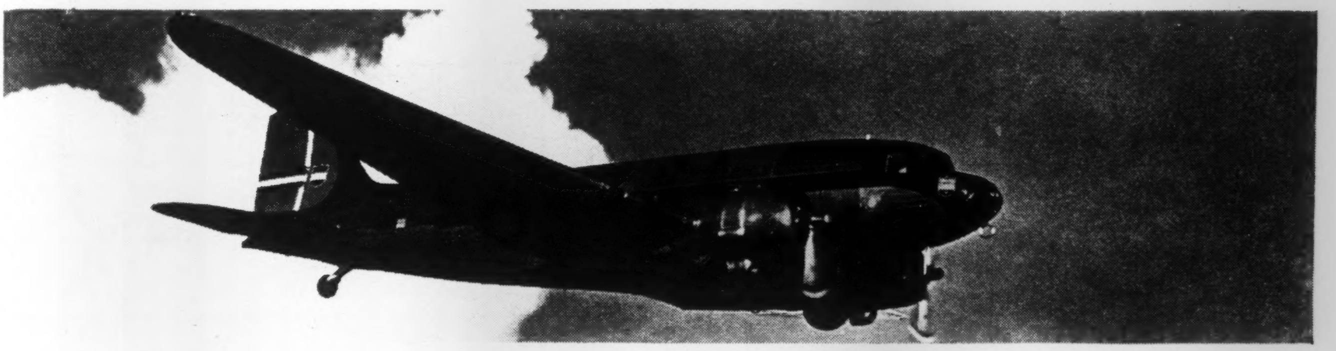


FIG. 10 DOUGLAS—DC-3 MAINLINER

comfort needs calling for considerable cabin furnishings, the useful load began to decrease percentagewise. The curve must, however, reverse itself again from now on, and better useful load - gross weight ratios will be obtained.

Wing loading, as shown in Fig. 13, indicates a definite trend upward. This is to be expected as higher wing loadings constitute a simple way of reducing drag. It is the author's feeling that this trend will continue, although the slope may taper off to some extent. This will be discussed in detail later.

The trend of power loading, as indicated in Fig. 14, was caused by the need for increased performance, and the rapid development of larger engines to permit this increase. As in the case of gross-weight variation in Fig. 11, this trend will probably "fan out," dependent upon the performance required of a particular airplane, such that it may satisfactorily do its job.

Figs. 15 and 16 are normal increases in maximum cruise velocity directly reflecting the trends expressed in the wing-loading and power-loading curves. Other basic aerodynamic improvements contributed materially to this trend, of course.

The range, as expressed in Fig. 17, shows what has been done, and just what the airplane can be designed to do. Ranges of future aircraft, however, will be determined by what is demanded by the specific operation to be accomplished.

Fig. 18 indicates the tremendous increases in take-off distance. Though this too, may fan out with choice of airplane in the future, still this shows the need for greater runway lengths.

ENGINES AND PROPELLERS

Two of the most important components of the airplane and, most naturally, vitally tied in with its development are the engine and the propeller.

Most of the early engines were of the water-cooled type although several of the most successful, particularly in France, were air-cooled. They varied from two cylinders to sixteen cylinders, the earlier ones used delivering only small powers, 30 to 50 bhp, Fig. 19. Gradually 100-hp engines were incorporated in the later airplanes. By 1916 and 1917, i.e., during the first world war, 300 to 400 hp was considered as extremely high. Reference to Fig. 19 indicates the tremendous strides which have been made, and the author believes it to be indicative of the trend to come.

Both air-cooled and liquid-cooled engines were used up to

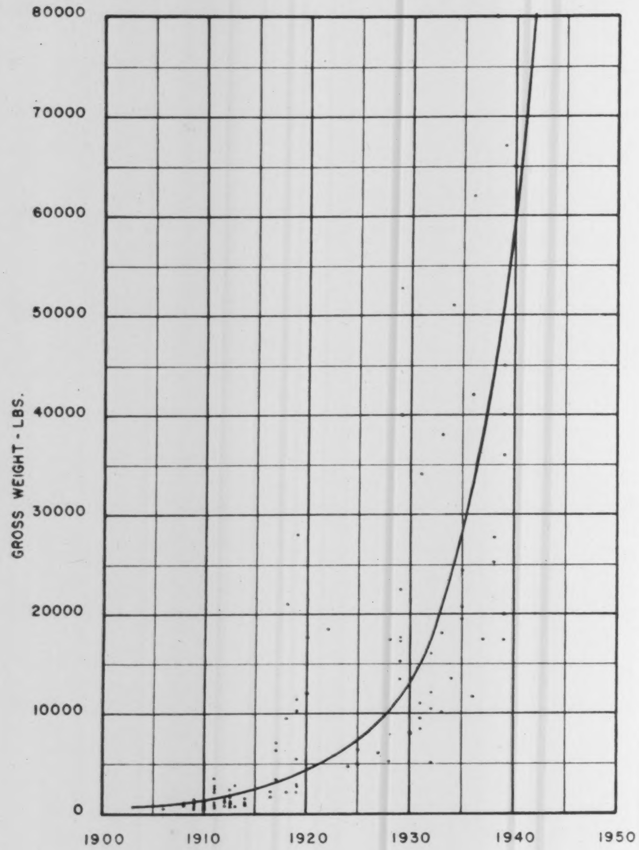


FIG. 11 GROSS-WEIGHT TREND

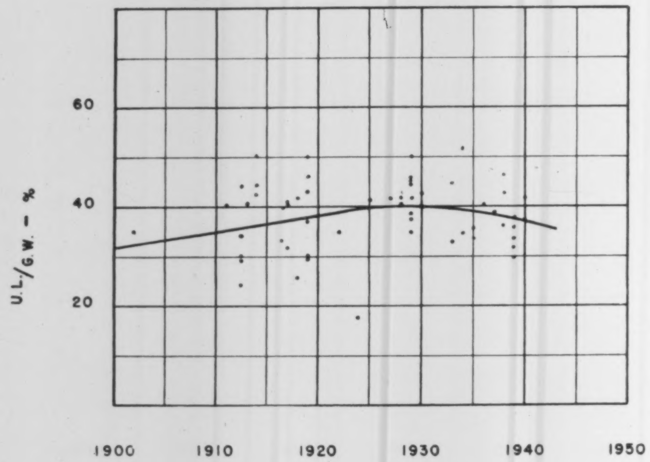


FIG. 12 USEFUL-LOAD-RATIO TREND

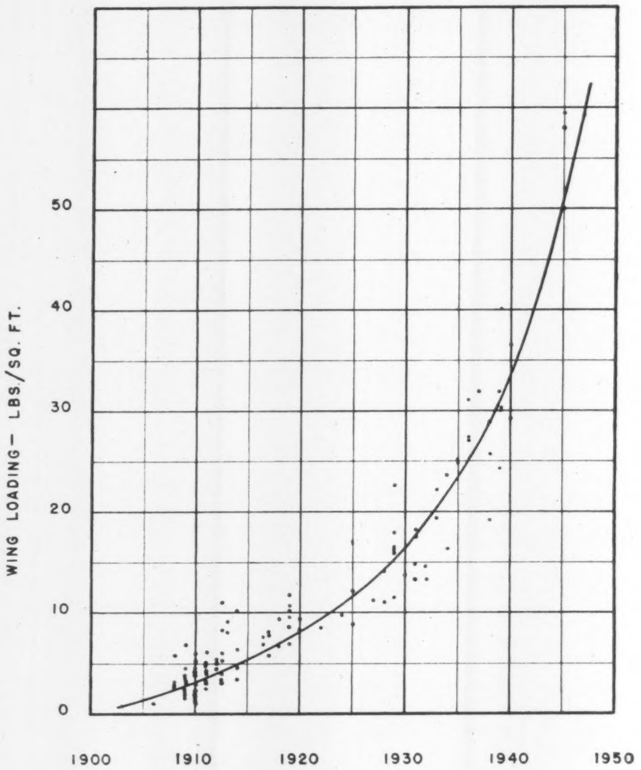


FIG. 13 WING-LOADING TREND

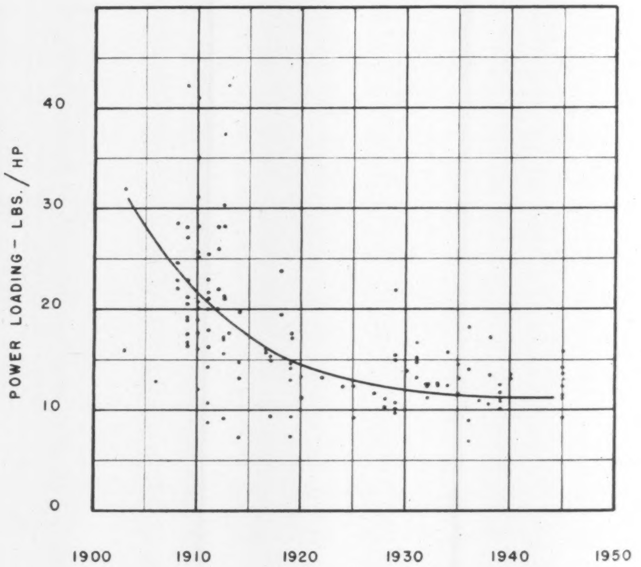


FIG. 14 POWER-LOADING TREND

1927. From here on, in the commercial field, mostly air-cooled were used, primarily because of weight saving, though much was done in liquid-cooled development in later years.

Weights of early aircraft engines were excessive for the amount of power which they developed. As will be noted in Fig. 20, the engine pound-horsepower ratio was extremely high. The Liberty engine, one of the most widely used after the first world war, had shown, by that time, improvement in this respect. Further improvement in materials, notably the development of aluminum alloy and magnesium, together with improved design, had reduced that ratio to the present value of slightly more than 1 lb per hp on air-cooled engines.

All of the early engines were naturally aspirated, and altitude performance was nil. Development of the internal supercharger gave the airplane its first chance at improved performance at altitude. It was first used commercially about 1930. Today, the integral supercharger is standard equipment for commercial aircraft. Exhaust-driven superchargers were first attempted in practice in 1919 but have not been used extensively except by the military.

One measure of engine development is total flight hours between major overhauls. In the early 1900's overhaul was accomplished after almost every flight. In 1919, a Martin bomber using Liberty 400-bhp engines made a long-range flight which exposed the engines for 147 flight-hours with ordinary servicing in between. This was a record at that time. In 1941, time between overhauls on major type engines was approximately 700 hr, with only normal servicing in between.

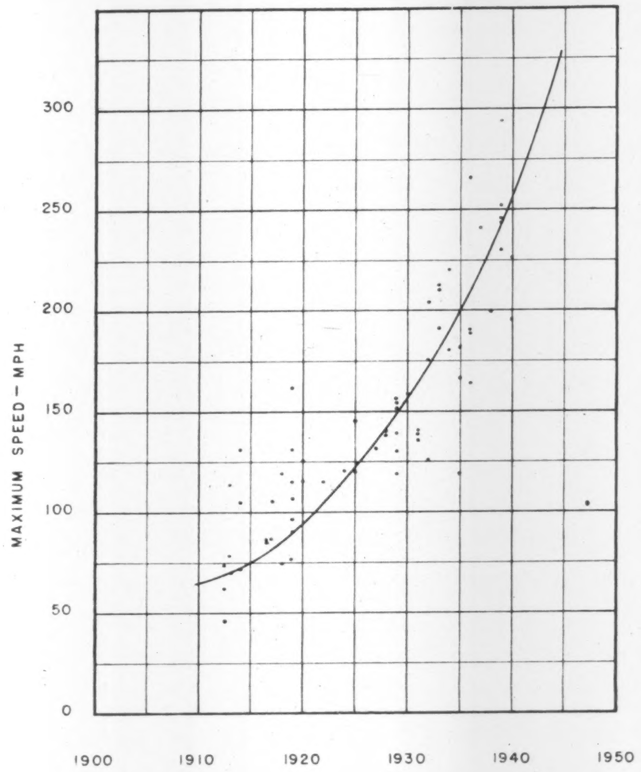


FIG. 15 MAXIMUM-SPEED TREND

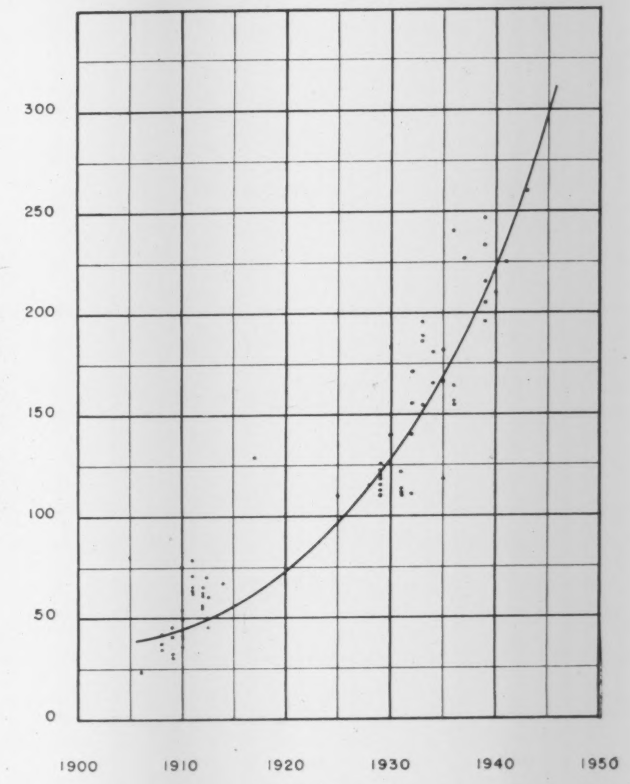


FIG. 16 CRUISE-SPEED TREND

Although the general engine field had been fairly well studied prior to the use of the gasoline engine in aircraft, this was not true of the air propeller. Probably the earliest use had been on balloons, but not much background had been obtained. The Wright Brothers' propeller of 1903 was of thin sheets of wood bent to the desired cross section (similar to the wing profile) and glued together. Hub drive was mainly through friction. It has been estimated that the efficiency of this propeller was somewhere from 57 to 60 per cent. One clever feature was the use of chains and sprockets as a means of driving, such that the revolutions of the propeller could be chosen as desired.

Some time in the early 1900's a Frenchman, Chauvieve, is claimed as first using the modern type of propeller airfoil. The under surface of this foil was nearly flat and the camber on the back side.

The Paragon propeller, quite similar in form to the Chauvieve, was used rather widely in the United States until about 1924. These were of quartered oak with splices of laminations occurring at the hub to permit matching of density of the two halves of these laminations, thus improving dynamic balance. Most propellers up to this time had been constructed of walnut and mahogany.

During the period of 1914 to 1918, the Army Air Corps used the toothpick-type propeller on trainers. It was so called because of its high aspect ratio, this contributing materially to its high efficiency.

The first important departure from wooden propellers was the development of the micarta type. This development began in 1917 and continued in use until 1929. These propellers were constructed by treating sheets of cloth with bakelite, cutting them into laminations, and pressing them into shape in a mold. They were capable of being made into thinner sections than the wooden type, which led to better efficiency.

During 1918, the first attempts were made toward fabrication of solid steel blades. Although these proved unsatisfactory, they formed the basis for the detachable-blade aluminum-alloy propeller. This Standard Steel Company development of aluminum alloy went into general use about 1923.

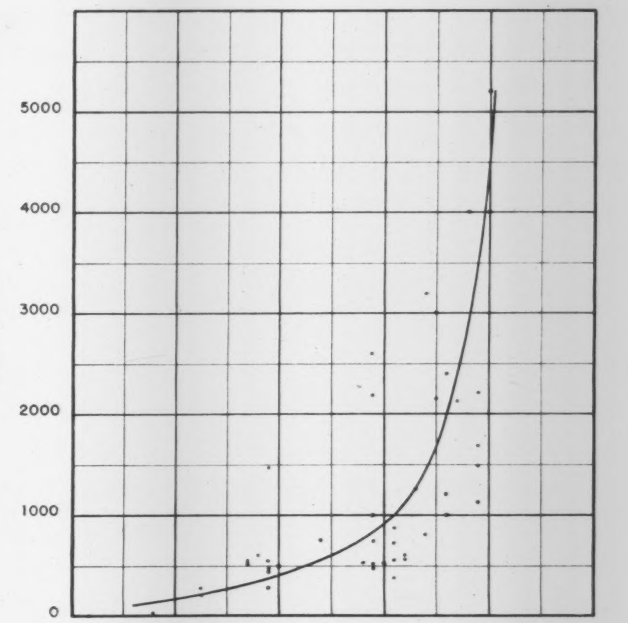


FIG. 17 MAXIMUM-RANGE TREND

In 1924, a type of pitch-changing gear was designed and was adapted by the Curtiss Company into a controllable-pitch propeller. It was electrically controlled and formed the basis for the present electric propeller.

Hamilton Standard introduced the two-position low-pitch and high-pitch propeller with the Boeing 247 transports. This was later modified by use of a centrifugal governor which gave constant-speed control.

The last important development to date in the propeller field was full-feathering operation. This was first applied to commercial craft in 1938. Use of full-feathering permits of complete stopping of the engine and propeller rotation at the time of an engine failure which eliminates additional drag, undesirable vibration, and possible additional damage to the engine.

It is interesting to note the improvement in propeller efficiency through the years. The Wright Brothers' propeller is stated as being between 57 per cent to somewhat over 60 per cent. Present-type propeller efficiencies, through the cruising range, vary from approximately 79 to 84 per cent.

PAST COMMERCIAL OPERATIONS

As stated in the beginning of this paper, the success of air transportation will depend to a great extent upon the airplane equipment flown. Therefore the results of technical development in aircraft should manifest themselves in the operations performed.

In order to illustrate this more clearly, a comparison of the general operating features and characteristics of a 1930 air-line system to that of a 1941 system will be given. For simplification and greater ease in understanding, the comparison is restricted to a typical transcontinental type of operation. Table 1 shows characteristics of 1930 types of commercial aircraft.

TABLE 1 ESSENTIAL CHARACTERISTICS OF 1930 FLYING EQUIPMENT

	Ford 5-AT-C, monoplane	Boeing 80A, biplane
Type	Day passenger	Day passenger
Take-off weight, lb	13500	17500
Weight empty, lb[a]	7750	10417
Useful load/gross weight, per cent	42	40
Wing loading, lb per sq ft	16.4	14
Power loading, lb per hp	10.0	11.1
Number engines	3	3
Horsepower per engine, maximum bhp	450	525
Cruising speed, approx, mph	110	115
Service ceiling, ft	19100	14000
Span, ft	77.8	80.0
Length, ft	49.8	55
Number passengers	12	16

[a] Does not include air-line equipment.

NOTE: Other types operated primarily for mail service but not included in this analysis are the following:

Boeing 40-B	Curtiss Pigeon
Boeing 95	Douglas M-2
Curtiss Falcon	Travel Air

1930 TRANSCONTINENTAL ROUTE

Airports and Airways. Airports and airways were just being developed at this period to suit the anticipated expansion. There were approximately 18 major airports and 111 intermediate fields. Lighted beacons, totaling 232, were in operation along this route. Reference to Fig. 21 illustrates the basic airway facilities available.

Most airports had sodded or oil surfaces and only a few had

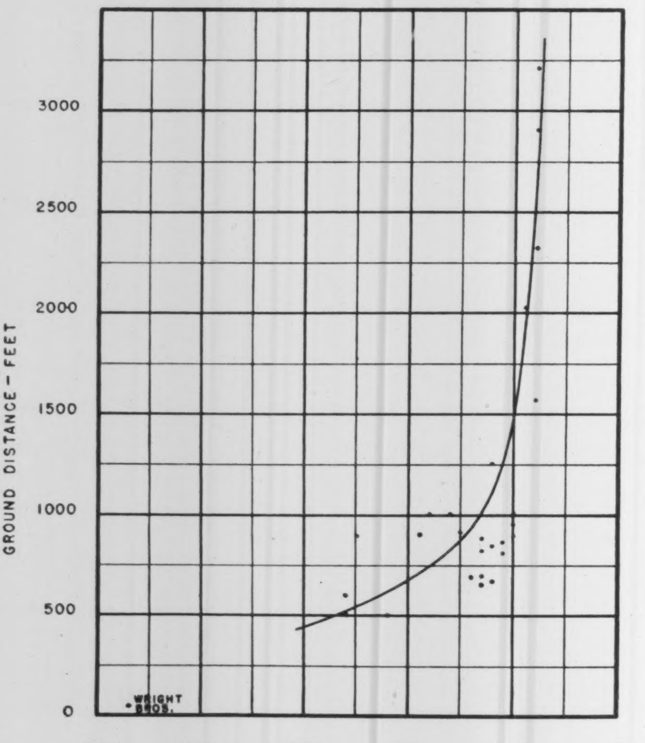


FIG. 18 TAKE-OFF DISTANCE TREND

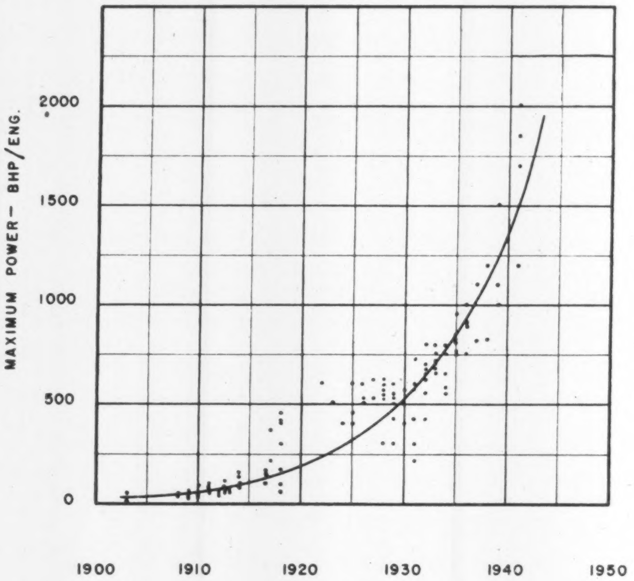


FIG. 19 HORSEPOWER TREND

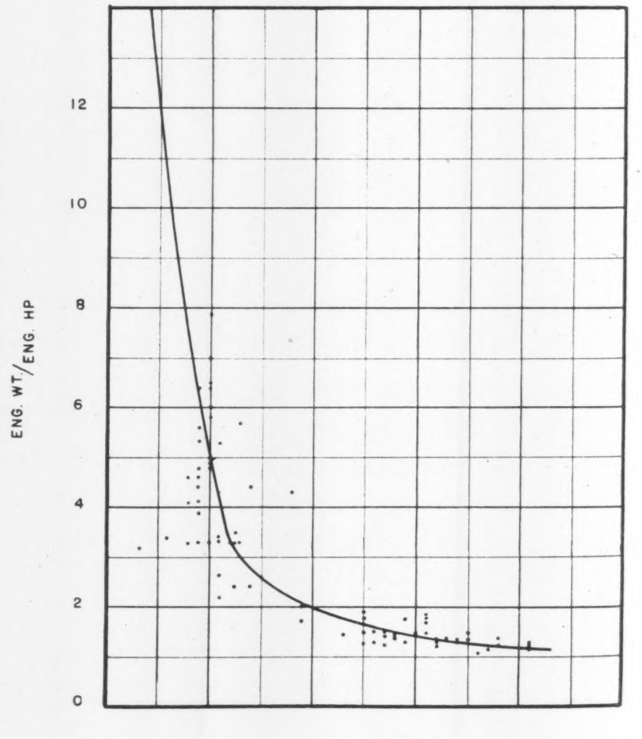


FIG. 20 ENGINE-WEIGHT TREND

runways. The larger fields had take-off and landing areas varying from 2000 to 5000 ft with the majority approximately 3000 ft long. Smaller field lengths varied from 1800 to 3000 with the average at 2500 ft. Fields at higher altitude had the longer runways of 4000 and 5000 ft.

Scheduled airplane movements in and out of airports were small. The three largest airports in use at the time had scheduled take-offs and landings as follows:

	Airport A	Airport B	Airport C
Total movements	28	40	33
Maximum 1-hr period	7	7	6
Maximum 6-hr period	19	23	15

Maintenance and Overhaul. Maintenance in 1930 aircraft was such that a complete check of the entire airplane was required almost every time a scheduled trip was completed. This included inspection and in many cases a teardown and overhaul of engine, engine accessories, controls, landing gear, and other actuating mechanisms.

Because of very rapid expansion, three repair depots were in operation, each handling all of the varied types of equipment. The problem was more one of doing what was necessary than having any well-established methods and control. Engines were changed at approximately 400-hr intervals, and the airplanes were tied up in the base for long periods.

Performance Analysis. The trip analysis, Table 2, shows the essential features of a typical trip operating westbound from coast to coast. Data were taken from actual operation reports.

The Ford Trimotor equipment was operated between stations NY and CG and the Boeing 80A airplanes from station CG westbound. Block-to-block speeds shown were good for this period. Average pay-load factors varied from 45 to 55 per cent of available capacity, dependent upon the portion of route flown.

TABLE 2 TYPICAL TRIP ANALYSIS—1930

Station	Trip length, miles	Average V_B, mph[a]	Average altitudes flown, ft	Normal stop times, min	Total elapsed times, hr	Average cost per ton-mile[c]
NY						
	418	99	2500 3500		4.22	$0.755
CV				:20		
	86	97	2000 3000		5.43	0.790
TL				:05		
	234	98	1500 2000		7.91	0.775
CG				14:28[b] (Overnight)		
	311	105	1500 2000		25.35	0.670
DM				:10		
	118	96	1500 2000		26.75	0.745
OH				:20		
	45	93	2000 3000		31.93	0.782
HK				:05		
	208	101	3000 4000		34.07	0.710
NQ				:15		
	216	102	4000 7000		36.44	0.708
CX				:15		
	258	106	8000 9000		39.12	0.690
RT				:10		
	159	95	8000 9000		40.97	0.735
SL				:30		
	201	101	5000 6000		43.46	0.710
EL				:10		
	230	104	7000 8000		45.84	0.700
RP				:15		
	189	100	3000 2000		47.98	0.720
SZ				:10		
	79	95	1000 2000		48.98[b]	0.768
SF						

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[a] Term V_B = block-to-block speed, or average miles per hour from time plane leaves terminal until arrival at next terminal.

[b] Direct connections were made at CG in 1931, eliminating night layover, and elapsed time coast to coast became 34.86 hr.

[c] Direct flying costs only, based on 1941 values and cost-estimation methods.

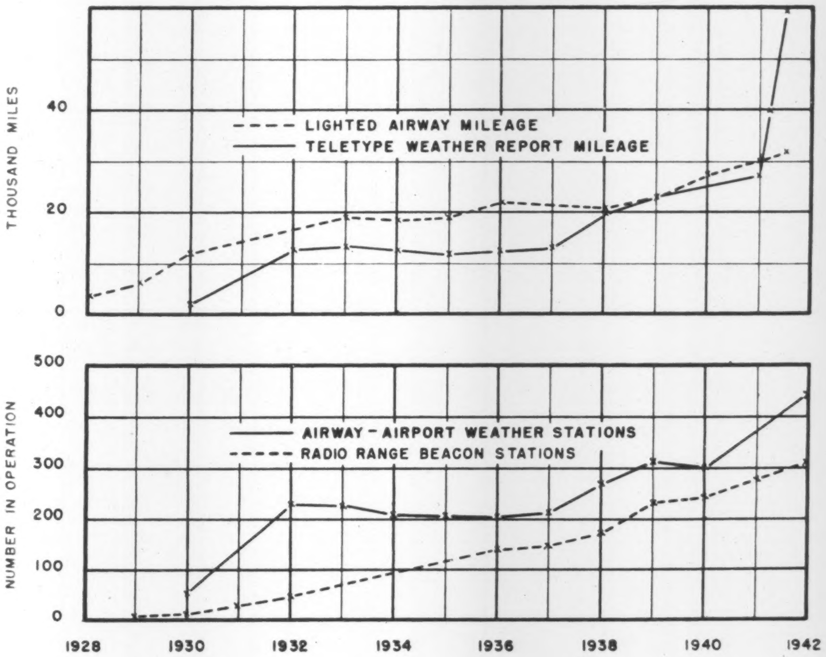

FIG. 21 AIRWAY-FACILITIES TREND

(Civil Aeronautics Authority data.)

The direct flying costs shown are computed costs, using the Mentzer-Nourse method. Inasmuch as dollar values have changed between 1930 and 1941, and may well change in the future, a common base for flying costs was felt to be desirable, in order that better comparison can be made between the 1930, 1941, and future analyses as included in this paper. It was primarily for this reason that actual flying costs were not used. Direct flying costs are only those costs which have to do directly with the actual operation of the aircraft and do not include overhead costs, such as administration, accounting, advertising and publicity, cost of building construction, maintenance, and the like.

The operation analysis, Table 3, is a condensed performance report giving the results of the operation during the 1930 period. Due to the method employed in air-line accounting practice, the transcontinental data could not be segregated, and therefore this information is expressive of the total number of routes flown by this particular air-line system. However, this does not materially affect any interpretation of these results, since the general relationship would still remain approximately the same.

TABLE 3 OPERATION ANALYSIS—1930

	Average per month
Number of scheduled trips	139
Per cent completed	58
Per cent completed on time	47
Delays at origin or stops en route, per 100,000 miles flown:	
Account weather	49.5
Account mechanical difficulty	11.7
Account passengers and mail arrival and loading	94.0
Number of unscheduled landings per 100,000 miles flown	
Account weather	21.7
Account mechanical difficulty	3.9
Utilization—hours:	
Ford 5-AT-C	175
Boeing 80A	190

1941 TRANSCONTINENTAL ROUTE

The year 1941 was chosen as the second step in this comparison, primarily because it reflected public acceptance of this mode of travel and, further, because 1941 was the last relatively stable year prior to abnormal conditions brought about by the present war.

Flying Equipment. The airplanes, as operated during 1941 over this transcontinental route, and their basic design features are detailed in Table 4.

TABLE 4 CHARACTERISTICS OF TYPICAL 1941 AIR TRANSPORTS

	Douglas DC-3 monoplane,	Douglas DST monoplane,
Type	Day passenger	Night passenger
Take-off weight, lb	25200	25200
Weight empty, lb[a]	16133	16457
Useful load-gross weight, per cent	36	35
Wing loading, lb per sq ft	25.5	25.5
Power loading, lb per hp	10.5	10.5
Number engines	2	2
Horsepower per engine (max), bhp	1200	1200
Cruising speed (approx), mph	188	188
Service ceiling, ft	25100	25100
Span, ft	95	95
Length, ft	64.5	64.5
Number passengers	21	14

[a] Does not include air-line equipment.

Airports and Airways. By 1941, lighted airways, radio ranges, weather-broadcast facilities, and other airways equipment had advanced considerably, Fig. 21.

All airports used in scheduled operation now had runways of concrete or paving. Runway lengths of the larger terminals were 5000 to 6000 ft; medium terminals 3500 to 5000; and intermediate fields with lengths of 2500 to 4000 ft.

Scheduled airplane movements had increased tremendously at major terminals. The same airports, as shown in 1930, now recorded the following:

	Airport A	Airport B	Airport C
Total movements	301	244	190
Maximum 1-hr period	44	21	23
Maximum 6-hr period	161	118	86

Maintenance and Overhaul. Maintenance and servicing had, by 1941, developed into a well-established procedure. Major and regular service stations were strategically placed across the route, staffed with competent mechanical personnel who carefully carried out the practices which were established. These can best be illustrated by means of Table 5, which classifies the major maintenance check procedure employed.

Overhaul and repair were concentrated in one major base. With only one major type of flying equipment, this simplified procedure immensely and gave closer co-ordination. Airplanes can also be routed into the repair base without upset of scheduled flying for all engine changes and routine overhaul in addition to major overhaul.

TABLE 5 MAINTENANCE CHECK PROCEDURE—1941

Check or maintenance period	Summary of work done
After each flight	Inspection and check of propellers, engines, cowling, accessories, electrical system, fuel systems, heating system, instruments, flight controls, general airplane fuselage, wings and tail, landing gear, and cabin. Complete refueling and reoiling. When airplane lays over at terminal for any period of time a complete engine ground run test is made.
Every 50 hr	Engines washed down, all parts tightened and inspected. Propellers completely checked and adjusted. All accessories and systems, as electrical, fuel, oil, and heating, completely checked out and adjusted. Fuselage and wing structure checked. Flight controls checked and tested. Landing gear and brakes inspected and adjusted. Complete engine ground test.
Every 125 hr	Same as 50-hr check except in addition: Oil drained, spark plugs changed, remove landing-gear wheels, check gear and brakes, pressure-test heating system, electrical-check ignition system, and other minor adjustments.

Routine engine change and overhaul and repair was accomplished every 675 flight-hours in 1941. This required complete teardown of all operating parts and minute inspection of every component. Major overhaul, which requires full teardown and major parts replacement where necessary, was accomplished at 6000 flight-hours.

Similar procedures are in use today.

Performance Analysis. The trip and operation analyses, Tables 6 and 7, for the 1941 period are given in a similar manner to the 1930 data. The basic data were again obtained from actual operating records and direct flying costs computed following the same method and constants. The average pay-load factor used was 66 per cent of available capacity.

FUTURE TECHNICAL DEVELOPMENT

The most important consideration, from the air-line operator's viewpoint in the development of any airplane, is the necessity of designing it to suit the specific work which it will be expected to perform.

Experience has shown that it is impractical and, what is more important, uneconomical to take any newly developed craft and arbitrarily operate it in an air-line system, which system, by its nature, must offer a varied and diversified service. The author is of the opinion that analysis of the job to be performed is paramount, developing from this the airplane or airplanes required to execute the desired operation. Only in this manner can truly efficient and economical operation be accomplished.

Technical development in the major component parts of the airplane is progressing with extreme rapidity. Not only because of the vital part of aviation in the present war, although this has accelerated development tremendously, but also because of the firm conviction of those in the industry that the surface has just been scratched and there remains much to be done. Some of the individual development and possibilities will be discussed, but many more of vital importance cannot be reviewed because of their confidential nature.

Drag and Lift Improvements. Considerable effort has been expended in research toward the production of new wing designs and airfoils. The wing itself is responsible for a major portion of the over-all drag of an airplane. New developments have been used in actual service which have shown decreases in this drag of more than 25 per cent. Auxiliary high-lift devices have been tested in conjunction with major wing designs which allow maximum lift coefficients of 3 and better. This high lift coefficient aids materially in maintaining desirable landing and maneuvering speeds.

TABLE 6 TYPICAL TRIP ANALYSIS—1941

Station	Trip length,[a] miles Sch. 1	Trip length,[a] miles Sch. 2	Average V_B, mph Sch. 1	Average V_B, mph Sch. 2	Average altitude flown, ft Sch. 1	Average altitude flown, ft Sch. 2	Normal stop times, min Sch. 1	Normal stop times, min Sch. 2	Total elapsed[b] times, min Sch. 1	Total elapsed[b] times, min Sch. 2	Average cost per ton mile Sch. 1	Average cost per ton mile Sch. 2
NY												
	98		157		4000 6000						0.262	
PG							:11		0.62			
	331		160		4000 6000						0.288	
CT							:10		2.87			
	51		146		4000 6000						0.261	
		745		166		8000 10000						0.341
AX							:10		3.35			
	33		110		4000 6000						0.260	
CV							:20		4.82			
	86		156		3000 5000						0.259	
TL							:10		5.70			
	234		156		3000 5000						0.278	
CG							:34	:21	7.37	4.49		
	145		151		3000 5000						0.267	
MO							:10		8.90			
	57	311	140	162	3000 5000	5000 7000					0.262	0.282
IX							:10		9.48			
	109		148		3000 5000						0.268	
DM							:10	:10	10.39	6.75		
	118	118	142	142	3000 5000	3000 5000					0.267	0.267
OH							:22	:15	11.39	7.75		
	138		152		4000 6000						0.268	
GI							:10		12.67			
		503		167	7000 9000							0.303
	365		160			7000 9000					0.291	
DV							:15	:15	15.14	11.01		
	380	380	128	128	10000 12000	10000 12000					0.290	0.290
SL							:24	:24	18.36	14.23		
	201		161		8000 10000						0.275	
EL							:15		20.01			
		431		162		8000 10000						0.295
	230		154		8000 10000						0.278	
RP							:10	:10	21.76	17.29		
	115		138		8000 10000						0.267	
		194		149		10000 12000						0.275
SZ							:10		22.77			
	79		130		4000 6000						0.258	
SF									23.55	18.76		

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[a] Schedule 1 is short-haul operation. Schedule 2 is long-haul operation.

[b] Direct flying costs only.

Further over-all decreases in wing drag have been obtained by reduction of wing area and increased aspect ratio. Increased aspect ratio gives reduced induced drag and is obtained by larger ratios of wing span to wing chord. Reduced wing area gives higher wing loadings which previously have been used with discretion because of questionable effect on take-off and landing performance, as well as performance in icing conditions. However, in the future, larger airports combined with greater take-off powers will nullify the take-off problem. It is also believed that the use of heat will be the answer to the icing difficulties. As pertains to maneuvering and landing conditions with high wing loadings, larger airports, together with complete instrument landing control and improved auxiliary high-lift devices will undoubtedly do much to permit increased landing and maneuvering speeds.

TABLE 7 OPERATION ANALYSIS—1941

	Average per month
Number of scheduled trips	1950
Per cent completed	91
Per cent completed on time	73
Delays at origin or stops en route per 100,000 miles flown:	
Account weather	33.2
Account mechanical difficulty	2.28
Account passenger and mail Arrival and loading	17.4
Number of unscheduled landings per 100,000 miles flown:	
Account weather	0.71
Account mechanical difficulty	0.535
Utilization, hours:	
Day plane	245
Night plane	320

This, then, indicates that wing loadings higher than used at present can be expected in the future. (Fig. 13.)

Improvements are also being made in nacelles which is that portion projecting from the wing and supporting the engine. Improved shape and relationship to the wing has decreased the drag. Later developed airplanes may have the nacelle, as such, completely eliminated with engines housed within the wing proper and a housing or small covering for the shaft to drive the propeller being the only projection from the wing. Considerable drag will thus be eliminated.

Engines and Propellers. Development of all types of aircraft engines should continue rapidly after the war. Weight-horsepower ratio will be reduced by means of improved materials and design. Reasonable analysis indicates that less than 1 lb of engine weight per hp can be expected with larger engines.

Present specific fuel consumption at normal cruising power is approximately 0.45 to 0.46 lb per bhp-hr. Several interesting research projects, which cannot be discussed, tend to indicate that decreases to as low as 0.37 to 0.38 lb per bhp-hr may be obtained.

Engines capable of delivering much higher powers than those used in commercial transport today will be available, and the author believes that a normal extrapolation of the curve shown in Fig. 20 would not be far from correct.

With concentrated effort being placed on supercharger development and the experience being gained in high-altitude operation in the present conflict, it will undoubtedly be possible to maintain satisfactory cruising powers at reasonable fuel consumptions well above 20,000-ft altitude.

Diesel aircraft engines have not been adequately developed to draw any definite conclusions. However, it is not believed that fuel consumption will be as amazingly low as has been claimed. Among other things the effective "burst power" on a Diesel is considerably less than on a regular gasoline engine, a feature which is desired. Nevertheless it is still the author's opinion that with reasonable development a good percentage of engines in the future may well be Diesels.

Propellers may be somewhat different from what we see today; wide blades, multiblades, dual or counter-rotating types, and probably completely reversible units. Effective efficiency of the present types of propellers may be roughly stated as being in the neighborhood of 80 per cent at cruising operation. It does not seem unreasonable to expect this to increase to at least 85 per cent in the future.

Higher-octane fuels for the present type of internal-combustion engine will provide one definite means of lower specific fuel consumption and less total fuel weight per trip. Fuel is the largest item of disposable load, and thus such a reduction means lower operating costs, assuming of course that cost of higher-octane fuels does not go out of bounds.

Useful-Load Ratio. Because so much emphasis has been placed on performance in the past, design for larger useful loads has to some extent been neglected. Considerable improvement, however, will be found in useful load - gross weight ratios in the future. This increase in load-carrying ability of the airplane will be obtained by improved structural design and special treatments to aluminum alloys prior to fabrication, such as prestretching. Larger aircraft will show a greater *UL GW* ratio than lesser-gross-weight types, because larger structures can be designed with better strength-weight ratios than smaller ones. Increase in the useful load - gross weight ratio results directly in increased carrying capacity of the airplane. Reference to Fig. 12 shows the present ratio to be about 36 per cent. This should be increased to well over 40 per cent in future larger commercial aircraft.

Airplane Balance and Loading. Positioning of passengers and cargo in present types of flying equipment, in order to keep the craft satisfactorily balanced for flight, is extremely important. This is required because present allowable ranges of center-gravity travel are small. Average travel is 12 to 15 per cent of the mean chord of the wing. This allowable range will have to be increased to 25 per cent or preferably 30 per cent in future aircraft to allow more flexibility in the placing of cargoes and passengers.

Loading and unloading of passengers and cargo will be accomplished in a manner altogether different from the present. Much delay is now caused by present type of "bucket brigade" loading and unsatisfactory stowage. Some stop times at terminals are excessive because of this. Future equipment must be so designed that, regardless of airplane size, complete loading, transfer, and unloading can be accomplished in 5 minutes. It is essential that ground time be kept at an absolute minimum.

Movable ramps capable of direct projection from terminal to plane; use of conveyer systems; larger trucks capable of hoisting the truck bed for elevated loading; and at larger terminals suitable docking; all these or some modification will probably be used in the future.

Landing Gear. Generally speaking the conventional type of landing gear (main plus tail wheel) will be discarded for the tricycle gear (main plus nose wheel). Later developments may well see the use of four wheels, two fore and aft, on either side of the fuselage.

The landing gear becomes an appreciable portion of the weight, empty, particularly in the larger planes, and studies are being made toward the possibility of eliminating the gear as such, during cruising flight. It is altogether probable that, in the distant future, aircraft will be designed using a form of assisted take-off and landing, eliminating the necessity of the present types of landing gear. This will aid materially in increasing the pay load.

Materials. Aluminum and aluminum alloys, with their broad background of experience, will probably not be replaced as the major aircraft material for some time to come. Wood and stainless steel offer interesting possibilities but, all things considered, do not show enough advantage over aluminum and its alloys at the present time to warrant its replacement. Magnesium will be used in increasing quantities in secondary structures and may be adaptable in some cases to the primary structure.

Plastics on commercial transport airplanes will probably be restricted to furnishings in cockpit and cabin and on accessory equipment.

A FUTURE COMMERCIAL OPERATION

The airplane will contribute immensely to growth and progress in the postwar world. It will create personal and business travel, never before possible by slower conveyances; facilitate exchange of ideas by personal contact; permit better understanding of others' problems; help create a higher standard of living throughout; and stimulate community of interest. This will aid in increasing trade levels, with all first-class mail, a large share of express, and a major portion of all passenger business regardless of class, using air transportation. And the job to be done by the airplane becomes more complex.

As stated previously, it is of prime importance that the flying equipment be intelligently designed to suit the requirements. It is not within the scope of this paper to analyze or discuss the anticipated markets and express the method for choice of aircraft. However, in order to illustrate the general characteristics of an air-line system which may be forthcoming in the future, the equipment, listed in Table 8, was chosen as being a possibility for a major transcontinental route. The basic sizes may or may not be correct, but the general relationship could be classed as an expression of the trend. These airplanes have been chosen to suit a particular purpose.

Airplane 1 is a long-range, *de luxe* passenger craft having sleeper accommodations. Only auxiliary baggage and mail space is provided. If the air-line also had international operation, such a type plane might suit this purpose depending upon the route. Extremely long range over water would require a larger airplane and the design would undoubtedly have to include cargo space in addition to passengers and mail. This particular analysis is restricted, however, to the transcontinental route to allow comparison with 1930 and 1941 operations.

Airplane 2 is a moderate-range passenger type of craft, in which the passenger accommodations are less luxurious than those in Airplane 1, and the passengers are in effect "packed in." This service will be comparable to "club" or the better class of coach travel. Baggage and mail space only will be provided.

Airplane 3 becomes a "variable-load carrier;" i.e., carries either passengers, or cargo, or both. This is accomplished by incorporating in the cabin a readily adjustable bulkhead separating passengers and cargo, allowing a choice of passenger-cargo ratio. Such flying equipment acts as a parallel feeder to the main trunk line, as well as a regular feeder serving off-line communities. It is expected that this market will vary and use of such an airplane will aid in maintaining higher pay-load factors. Passenger accommodations are moderate and simple.

During development of the air-cargo market, Airplane 3 will probably suit the demand. As the air-cargo field expands, however, a fourth type, Airplane 4, may be required. This will be wholly a cargo airplane and is included in the following projection.

For those smaller communities, where air-cargo service is desired, the use of the "pickup" system may be well justified. This, of course, pertains to cargo operation only. However, it was felt that such analysis would not necessarily come within the scope of this paper and, therefore, is only mentioned here as a possibility in future expanded operations.

Airports and Airways. Large terminals will require runways 8000 to 10,000 ft long with many parallel runways to allow for multiple airplane movements. Movement of aircraft in and out of large terminals is estimated as follows:

Total movements........................	750
Maximum 1-hr period....................	75
Maximum 6-hr period....................	300

Complete instrument landing and control facilities will be available.

TABLE 8 GENERAL CHARACTERISTICS OF POSSIBLE POSTWAR AIRPLANE TYPES FOR TRANSCONTINENTAL SERVICE

	Airplane 1 Low-wing monoplane	Airplane 2 Low-wing monoplane	Airplane 3 High-wing monoplane	Airplane 4 High-wing monoplane
Take-off weight, lb............	126500	80000	43000	32500
Landing weight, lb............	110000	70000	40000[b]	30000
Weight empty, lb[a]...........	76770	46405	24925[b]	19050
Useful load-gross weight, per cent.......	40	42	42[b]	41
Wing loading, lb per ft.........	75.0	57.0	32.3	32.6
Power loading, lb per hp.....	10.5	9.3	12.7	13.0
Number engines.	4	4	2	2
Horsepower per engine (max), bhp..........	3000	2150	1700	1500
Cruising speed, mph[c].........	266	260	212	210
Range (max), miles.........	2500	1200	750	1300
Span, ft.........	141	118	115	100
Length, ft.......	118	97	73	69
Number passengers				
day, max......	100			
night, max....	56	75	52 or	None
Mail or cargo, (max), lb[d]....	4500	3000[d]	14100	10400
Type gear.......	Tricycle	Tricycle	Tricycle	Tricycle
Cabin supercharging......	Yes	Yes	None	Cockpit and some compartments

---

[a] Does not include air-line equipment.
[b] Based on cargo-plane condition.
[c] At take-off weight 10,000-ft altitude, 60 per cent rated power.
[d] With full passenger load.

Some minor terminals as now established may develop into medium terminals as expansion occurs. These terminals will also require complete instrument-landing equipment and many parallel runways, although not to as great an extent as the large terminal. Runway lengths required are between 6000 to 8000 ft. Airplane movements will probably be as follows:

Total movements........................	400
Maximum 1-hr period....................	50
Maximum 6-hr period....................	200

At feeder terminals, runways must be 5000 to 6000 ft in length. Such airports will be similar to the present average-sized terminal. Instrument landing and control is required. Airplane movements are estimated as follows:

Total movements........................	125
Maximum 1-hr period....................	10
Maximum 6-hr period....................	35

Strip-type runways, that is, one major runway, will probably be in considerable use in the future, at least at feeder terminals. These will be 8000 to 10,000 ft long with the terminal located in the center.

Maintenance and Overhaul. Maintenance procedure or use of periodic check and adjustment will still follow the basic method which is now being used. With improvement in equipment design and operation, the magnitude of work necessary per airplane may be decreased, thus simplifying the maintenance work required.

"Trouble shooting" or analysis of improper equipment operation at en-route terminals is most inefficient and is responsible at present for numerous delays and lengthy stop times. Future equipment will be so designed that complete replacement of a malfunctioning assembly or unit can be made during a scheduled stop. This may apply even to the complete power plant.

As concerns overhaul, with 3 or 4 different types of flying equipment, it may be desirable to have a like number of repair bases, located at the best point en route to suit the particular airplane operation. Bases may be combined maintenance-

TABLE 9 TYPICAL TRIP ANALYSIS—FUTURE AIRPLANE 1

Station	Trip length, miles	Average V_B, mph	Average altitudes flown, ft[a]	Normal stop times, min	Total elapsed times, hr	Average cost per ton-mile[b]
	Airplane 1 schedule (85 per cent pay-load factor)					
NY						
	745	240	10000 20000			$0.166
CG				:10	3.10	
	932	246	12000 25000			0.165
DV				:10	7.06	
	1005	249	12000 25000			0.164
SF					11.47	
			(Alternative)			
NY						
	1677	256	12000 25000			0.177
DV				:15	6.55	
	1005	249	12000 25000			0.164
SF					11.05	

---

[a] Altitude variation to allow for choice of winds and weather.
[b] Direct flying costs only.

TABLE 10 TYPICAL TRIP ANALYSIS—FUTURE AIRPLANE 2

Station	Trip length, miles	Average V_B, mph	Average altitudes flown, ft[a]	Normal stop times, min	Total elapsed times, hr	Average cost per ton-mile[b]
	Airplane 2 schedule (75 per cent pay-load factor)					
NY						
	425	220	10000 20000			$0.145
CV				:05	1.93	
	320	210	10000 20000			0.150
CG				:10	3.53	
	429	220	10000 20000			0.145
OH				:05	5.54	
	503	225	10000 20000			0.141
DV				:05	7.87	
	380	215	10000 20000			0.148
SL				:10	9.72	
	431	221	10000 20000			0.145
RP				:05	11.83	
	194	198	10000 20000			0.155
SF					12.89	

[a] Altitude variation to allow for choice of winds and weather.

[b] Direct flying costs only.

TABLE 11 TYPICAL TRIP ANALYSIS—FUTURE AIRPLANES 3 AND 4

Station	Trip length, miles	Average V_B, mph	Average altitudes flown, ft[a]	Normal stop times, min	Total elapsed times, hr	Average cost per ton-mile[b]
	Airplane 3 schedule (75 per cent pay-load factor)					
NY						
	98	150	2000 4000			$0.120
PG				:05	0.62	
	54	160	3000 5000			0.123
XA				:05	1.06	
	277	170	6000 10000			0.102
CT				:05	2.76	
	51	150	3000 5000			0.123
AX				:05	3.18	
	33	145	2000 4000			0.132
CV				:05	3.49	
NOTE: Schedules similar for rest of route and for feeder to off-line points.						
	Airplane 4 schedule (70 per cent pay-load factor)					
NY						
	425	177	10000 20000			0.103
CV				:05	2.40	
	320	171	10000 20000			0.104
CG				:05	4.35	
	429	177	10000 20000			0.103
OH				:05	6.85	
	503	181	10000 20000			0.102
DV				:05	9.73	
	380	175	10000 20000			0.104
SL				:05	12.08	
	431	177	10000 20000			0.103
RP				:05	14.60	
	194	165	10000 20000			0.105
SF					15.85	

[a] Altitude variation to allow for choice of winds and weather.

[b] Costs are direct flying only and do not include overhead or pickup and delivery.

TABLE 12 OPERATION ANALYSIS—FUTURE

	Average per month
Number of scheduled trips	6000
Per cent completed	100
Per cent completed on time	96
Delays at origin or stops en route per 100,000 miles flown:	
Account weather	3.1
Account mechanical difficulty	0.6
Account passenger and cargo arrival and loading	10.0
Number of unscheduled landings per 100,000 miles flown:	
Account weather	0
Account mechanical difficulty	0.3
Utilization, hours:	
Airplane 1	350
Airplane 2	425
Airplane 3	400
Airplane 4	330

and-overhaul terminals where major checks and engine changes may be accomplished regularly between schedules. Airplanes would not be routed into the base for any length of time, except for major overhaul.

Performance Analysis. The trip and operation analyses, Tables 9, 10, 11, and 12, are based on a probable transcontinental airline operation. As previously mentioned, it has been assumed that the airplanes used have been properly chosen to suit markets which are anticipated. Each airplane has been used for its most logical operation. In order further to guarantee schedule reliability, power has been established for "no-wind" condition at approximately 5 per cent less than present practice to allow some latitude to overcome head winds. Present power (cruise) limit used is about 63 per cent of rated, this percentage being used in this analysis as maximum for head wind condition and 58 per cent for cruise with zero wind.

CONCLUSION

In conclusion let us examine the results of the three commercial operations analyzed, 1930, 1941, and postwar. Reference to comparative curves, Figs. 22 to 25, inclusive, shows the postwar points without date. Because of the well-recognized im-

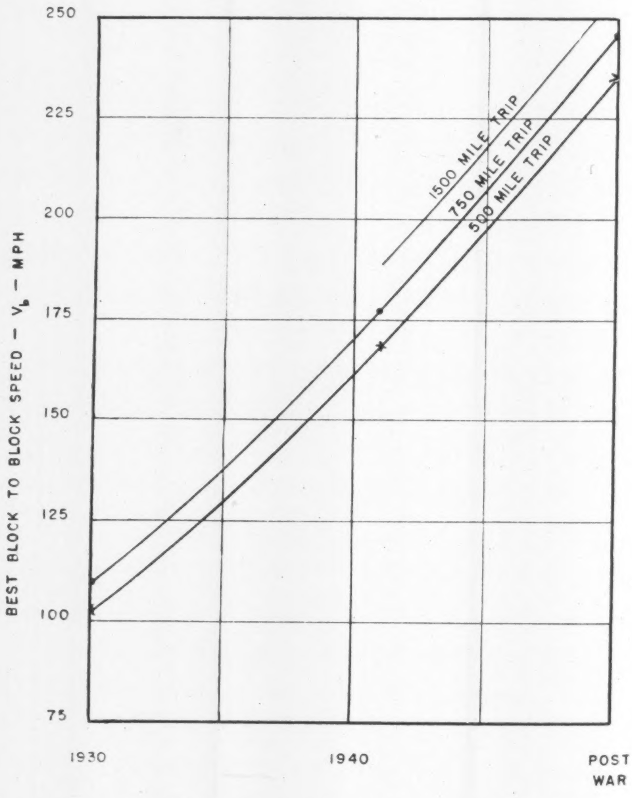

FIG. 22 BLOCK-TO-BLOCK SPEED TREND

possibility of determining definitely just when we will return to normal times, this point was arbitrarily chosen. Moving it back or forth several years would not change materially the trends of the curves. But it can be stated with reasonable certainty that the airplane, both in design and operation, can and will justify these trends.

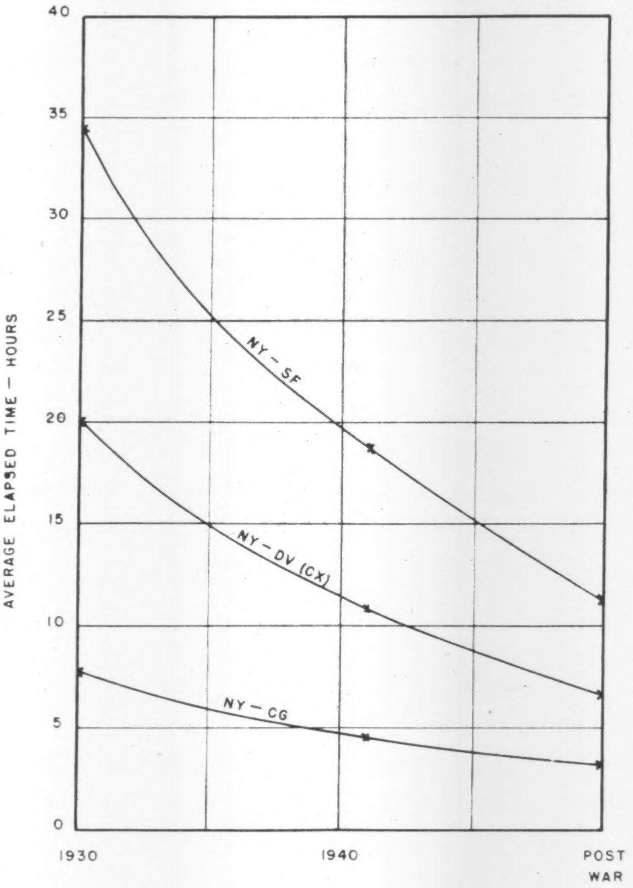

FIG. 23 ELAPSED-TIME TREND

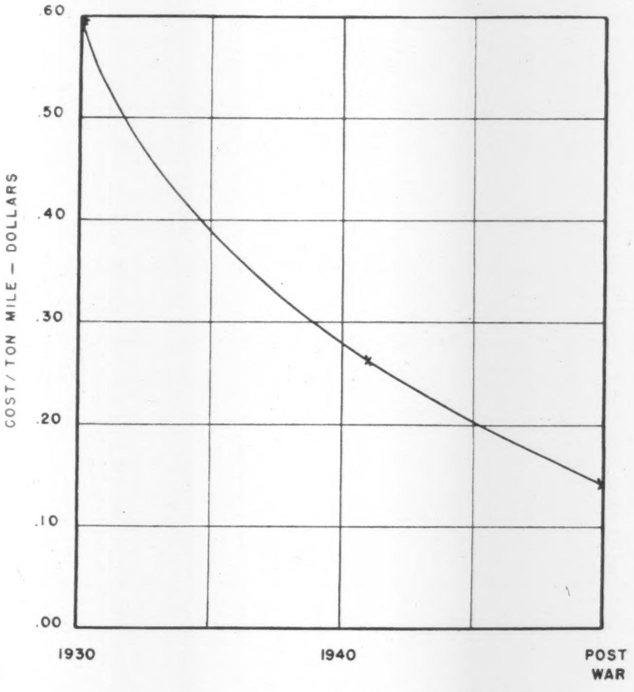

FIG. 24 DIRECT-FLYING-COST TREND
(500 mile trip length; adjusted for 75 per cent pay-load factor. Only passenger aircraft suitable for this trip length used. Adjusted for comparable passenger service.)

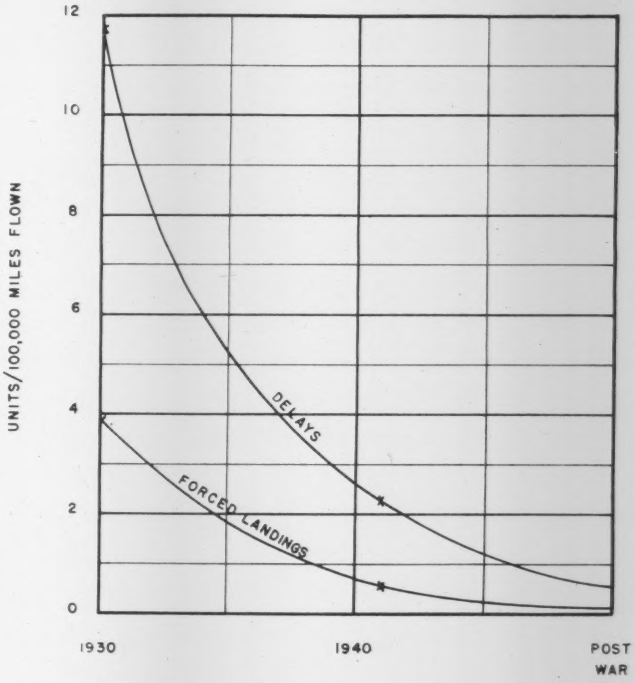

FIG. 25 DELAYS AND FORCED LANDINGS
(Caused by mechanical difficulty.)

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EDUCATION *for* MANAGEMENT

By HAROLD VINTON COES

PRESIDENT, THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

MANAGEMENT has been tersely defined as getting things done through the efforts of other people; but before we proceed further, let us distinguish between administration, management, and organization. Oliver Sheldon in his book, "The Philosophy of Management," offers the following definitions:

> Administration is the function in industry concerned in the determination of the corporate policy, the co-ordination of finance, production, and distribution, the settlement of the compass of the organization, and the ultimate control of the executive.
>
> Management proper is the function in industry concerned in the execution of policy, within the limits set up by administration, and the employment of the organization for the particular objects set before it.
>
> Organization is the process of so combining the work which individuals or groups have to perform with the faculties necessary for its execution that the duties so formed provide the best channels for the efficient, systematic, positive, and co-ordinated application of the available effort.
>
> Organization is the formation of an effective machine; management, of an effective executive; administration, of an effective direction. Administration determines the organization; management uses it. Administration defines the goal; management strives toward it. Organization is the machine of management in its achievement of the ends determined by administration.

Philosophy demands that we conduct our practice according to principles or laws. Have we linked all our new developments in management technique to some fundamental connection and reviewed them in the light of some ultimate purpose, or are we mere opportunists of a day?

Management, broadly, is the development and co-ordination of people and not the direction of things. It involves two major responsibilities:

1 Planning what we want people to do and how we want them to do it. This, of course, involves also planning the facilities to be used.

2 Operation control, that is, means for the control of the various functions so as to require people to work according to the plan and its prescribed methods and means for ascertaining that this is being done. This means:

(*a*) A philosophy of management.
(*b*) A sound organization structure.
(*c*) Good supervision.

WHAT CONSTITUTES SOUND ORGANIZATION

What constitutes sound organization structure? In my opinion the following basic principles include about all there is to it:

1 Separation of the functions of the business, such as sales and distribution, production, purchasing and procurement, financial and accounting, engineering, research and development, and industrial relations.

2 Setting these line functions up with their logical subdivisions so there is no overlapping or conflict and so that no individual receives direct orders from more than one individual—his immediate superior. He may, however, receive aid and advice from staff officers or assistants.

3 Clean-cut distinction between line and staff functions and functional control.

4 Clean-cut specification of each management job in the entire management sequence at the several management levels, to avoid divided responsibility.

5 Suitable and adequate delegation of authority and responsibility for each member in the management sequence varied in accordance with the management level.

6 Selection for each position in the management sequence for each management level of the most suitable and competent individual, without fear, favor, or political influence.

Those of you who have had experience in organized sports will recognize that the foregoing principles generally apply throughout—to football, for example. There are various positions on the team. There are several management levels—coach, captain, quarterback—with varying degrees of responsibility. There are clear-cut functions to perform. The players do not expect to receive signals from the coach or a tackle. Each one knows what his job is and what he is supposed to do when the signal, or command, is given. The strategy is varied to suit conditions, as it must also be varied in business. The objective is clear—to win the game. The selection of members of the team is usually made on the basis of fitness, skill, competence, and ability to co-operate and obey orders. We do not confuse positions. We do not spoil a good quarterback by trying to make him center or fullback. A player does not reach for the ball when the signals call for someone else to receive it. We all know what happens when a limelight player proceeds on his own to do what he wants to do, regardless of whether it fits into the previously conceived play. We all know what happens when some incompetent and unskilled player is placed on the team through influence or politics.

A management group in business is in essence a team. When it is trained as a team, with competent individuals at each post, and when it is properly and expertly captained, we generally have a successful, aggressive, hard-hitting business organization.

MANAGEMENT PROBLEMS ARISE FROM VIOLATION OF PRINCIPLES

Management frequently violates some of the foregoing prin-

The Basic Principles of Organization

1 Separation of the functions of the business, such as sales and distribution, production, purchasing and procurement, financial and accounting, engineering, research and development, and industrial relations.

2 Setting these line functions up with their logical subdivisions so there is no overlapping or conflict and so that no individual receives direct orders from more than one individual—his immediate superior. He may, however, receive aid and advice from staff officers or assistants.

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ciples and then wonders why it is in trouble. In fact, a substantial portion of the problems that are brought to the consulting management engineer actually emanate from violation of the cardinal principles of organization such as the following:

1 Confusion between line and staff duties (staff officers giving orders to subordinates of line officers).
2 Overlapping authority (two or more executives having control of sections of the same business function).
3 Responsibility without adequate delegation of authority (failure to recognize that adequate authority must go along with responsibility if responsibility is to be discharged).
4 No clear definition of duties. This usually results in overlapping authority, confusion, and conflict.
5 Executives cut across organization lines of flow of authority in issuing orders. The result is confusion and lowered morale. A clean-cut definite organization is the means for orderly transmission of orders from the top to the bottom and for a reverse flow of information to the top. Hence it is a communication system.
6 Executives do not know how to delegate authority or what authority to delegate, but they will delegate responsibility, because they fear some one will become more important than they are.
7 Responsibility and authority are frequently assigned to an individual by executives because they like him, regardless of whether he is competent, through training, skill, experience, and character, to fill the position; probably the wrong man is chosen for the job.
8 No clear-cut philosophy of management.

Violations of these same fundamental principles cause confusion and waste in government administration. The various administrative functions and agencies are not properly distributed or co-ordinated and there is too much overlapping of authority and responsibility since, in too many cases, no one function in its entirety is completely under the control of a single head. Only recently the Truman Committee significantly pointed out that there are too many czars assigned to attain specific objectives in the production field. Lines of authority are confused even on paper. As a practical matter they breed disputes. This is all too true. The Administration does not understand the fundamental principles of organization, such as the delegation of authority and responsibility. The President has shown all along a passion for divided authority among his subordinates. However, he can no more violate these fundamental principles with impunity and avoid confusion than can any top business executive, but the Administration's violations cause much more widespread devastating confusion and economic waste.

QUALIFICATIONS OF A TOP EXECUTIVE

What are the important qualifications of a competent top executive? May I suggest the following:

1 Character, that is, honesty, integrity, loyalty, truthfulness, fairness, tolerance, firmness.
2 Orderliness in mind and in action.
3 Poise and control of temper, not desk pounding.
4 Respect for time, its value, and its use.
5 Ability to assume responsibility.
6 Ability to co-operate.
7 Ability to take and to give constructive criticism.
8 Ability to compromise when necessary.
9 A sense of humor.
10 Broadmindedness.
11 Action without procrastination.
12 Wisdom to understand that it is no sign of weakness to seek help from competent sources.
13 Clarity of thought—the ability to reason from the facts, draw sound conclusions, and then act.
14 Good judgment, acting intuitively at times, without the aid of logical reasoning. In fact, with only the facts at hand at the time the decision must be made, logical reasoning from the facts will frequently produce a conclusion at direct variance with what judgment dictates.

Chester I. Barnard, in his lecture at Princeton University in 1936, entitled "Mind in Everyday Affairs," distinguishes between the diagnosis of judgment and logical reasoning. He said:

> Because of two divergent and mutually distrustful types of mental processes, broadly termed the logical and nonlogical, a bias exists against the latter that amounts to suspicion or even contempt, and behind this bias lies the very human urge and need to justify opinions, actions, and decisions, in the light of logic and sound reasoning.
>
> Such a bias is unwarranted and dangerous as well, tending to prevent use of the nonlogical or intuitive mental process in situations where logical thinking will not serve. The bias exists despite the fact that actions and decisions are being made all the time not as a result of conscious and deliberate reasoning, but on what is variously termed good judgment, inspiration, or even hunch, focusing, perhaps unconsciously, accumulated knowledge and experience on the problem at hand during the time available in order to arrive at what seems the sensible decision.
>
> Use of either type of mental process exclusively too often leads to incorrect conclusions. Neither alone is sufficient. Even in the exact sciences a modicum of the nonlogical is required. That individual is best equipped who can use both in correct proportions for the problem at hand, turning freely to intuition, speculation, judgment, at the point where reasoning, formulae, mathematics, facts, precedents are not adequate.

I can hear someone say, "That is an impressive list of qualifications. I don't believe executives possess all of them." Being human beings, they don't. The problem is to select the individual who, other things being equal, such as training, experience, background, skill, and character, possesses the greatest number of the requisite qualifications and then to develop in him to the greatest extent possible those qualifications in which he is deficient. That is the best that can be done.

MANAGEMENT'S JOB IS TO CO-ORDINATE MEN, MARKETS, AND MONEY

After we have set up management and have organized it, what are we going to do with it? What is it supposed to do? The administrative function should define this and the policies.

Top management has the job of co-ordinating the forces generated from the three basic economic elements—Men, Markets, and Money—which comprise practically all business enterprises and of maintaining equilibrium between them. Competent management must have a good workable understanding of these elements and the forces released and must know how to guide the business so as to maintain equilibrium. It must consider the fact that in modern industry today, at least in this country, the workers in the plant, through their purchase of goods, their savings, life insurance, and ownership of securities, are components of both the goods-and-services markets and the capital-supply market.

Sometimes it appears as though satisfaction of the demands emanating from these three basic elements—Men, Markets, and Money—were irreconcilable. In a country such as ours, free enterprise supports us all and the government functions as the referee of the rules prescribed for the conduct of the game of business.

Unfortunately, at times the referee forgets he is a referee and proceeds to run with the ball, and that causes confusion. The markets think prices are too high and proceed to go on buyers' strikes. Money (capital) thinks its return is too low for the risk incurred; it sulks; and money cannot be secured to finance more facilities and to produce more goods at lower cost to satisfy more buyers. Men (labor) think they are entitled to a greater share of the earnings of business, or management itself has grandiose ideas of what it is worth and proceeds to divert earnings from both men and money (labor and capital). Any one of the foregoing moves, if definitely out-of-line, tends to throw out of balance the forces in which business must operate.

If government, through unsound and discriminatory tax measures, fiscal policies, or unwise legislation, violates the basic principles underlying the American free-enterprise system, then equilibrium of the foregoing economic forces is upset.

It is management's job to conduct the business so as to keep these forces in balance. To the extent that the distortion of the forces is beyond an individual management's control, its job is to co-operate with industry, with labor, with government, or with consumers (the market) in constructive measures to bring these forces back to equilibrium. The formula for doing this is quite simple. Increased purchasing power is derived from increasing production and lowering costs and prices through reinvestment in facilities, research, management methods, and other means, thereby increasing the productivity and earnings of men and facilities.

What does the man factor (labor) want?

Labor in general wants a fair share of the results of its productivity.

What does money (capital stockholders) want?

It wants a fair return on the investment, commensurate with the risk taken, and it wants the ability to set aside surpluses to enable the enterprise to weather economic storms.

What does the market want?

It wants goods suitably priced commensurate with the quality or grade offered.

Do these claims seem inordinate? No. They are at times made so through avarice or through ignorance of the respective parties, including government, of the basic economic laws that govern in our free-enterprise economy.

Dr. Carl Snyder in his fascinating book, "Capitalism the Creator," has demonstrated that a close correlation has existed over a long period of time in this country between wages and new capital investment; that wages went up in proportion to the increasing investment of new capital in facilities to produce goods at lower costs.

ENGINEERS SHOULD KNOW MORE ABOUT MANAGEMENT

What has all this to do with education for management? It has this bearing. It means that to be a good manager and a competent executive one has to understand the principles and laws involved, their application, and how they work. It is not enough to be just a good engineering technician, for example, to qualify for an important managerial position. One must know more about management and economic laws and principles and their application, more about what constitutes sound industrial relations, more about what the markets want and why, more about how to get along with government.

There is no way that engineers can avoid relations with management; nor is it possible for them to avoid obtaining a good working knowledge of the basic principles of modern management, of sound organization, or of equitable labor relations if they expect to get ahead in their profession and advance in their business.

Yet too many engineers do not know enough about management. One may be an expert in his own field but he frequently makes grievous mistakes when he assumes that he is an expert in another field with which he is not thoroughly familiar, such as management.

It is not enough for an engineer to be right, he must be persuasive as well and he must be able to sell his ideas to others.

My experience has taught me that a substantial portion of the problems that come to me in my professional capacity arise from violations of organization principles.

Consider the problems, for the moment, in the field of personnel management. One authority has distinctly stated them as follows:

> The truth might as well be faced, the standards for the personnel profession are loose and ill-defined and this goes for many managerial jobs. This is principally the fault of personnel executives themselves and partly that of top management. The former have made no real sustained and co-operative effort to develop any professional standards, while the latter have all too frequently been careless in selecting men for the important job of handling the industry's human relations.

May not engineers have some responsibility in helping to remedy this situation? They know how to establish standards; perhaps that technique can be used to assist here.

The engineer should take an interest in industrial relations and should contribute sound thinking on the subject. He should become familiar with the problems of the day's work from labor's point of view. There is more to this than just applying the techniques of time and motion study and job analysis, subjects in which many engineers have been greatly immersed and to which they have made real contributions. There are human values and human aspirations which must be considered, and it is with these that the engineer must be constructively concerned.

Here is the way capitalism and profit can be made to benefit labor and produce better living, according to James H. McGraw, president of the McGraw-Hill Publishing Company:

1 Constantly improve the equipment available for the worker.

2 Use the lowered costs thus produced to
   (*a*) Lower prices to consumers
   (*b*) Raise wages
   (*c*) Provide incentives for invention, leadership, and investment
   (*d*) Lay aside "seed money" that can be used to start over again at Item 1.

There is evolving an art in guiding management by means of statistical control. The determination of what is the range or belt of probabilities and how this technique can be applied to assist management in effective regulation and control of a business is important.

One authority has stated: "Our management battle is a hard one. Opposition (our enemies) is grim and desperate. A new and quicker production idea, a faster employee-training method, a few months of life gotten out of an old machine, a department's bettering of last month's record, a subcontractor educated to better management policies; this is the stuff of which management victories are made."

Do not engineers have responsible relations to management with respect to many of the foregoing items in furtherance of the war effort?

We have successfully solved many of the problems of mass production, but in many respects our technique of mass distribution is way behind our technique of mass production. After the war the engineer could well direct some of his talents to the problems of mass distribution.

After all, management is directing, guiding, training, and co-ordinating people. You can shout at a full-automatic lathe until you are blue in the face and nothing will happen except a rise in your blood pressure. But you can direct a skilled workman to operate the machine along predetermined lines and the required results will be forthcoming.

I like to think of management as the catalytic agent between ownership, consumers, employees, industry, and society (government) on the one hand, and the various functions of the business, such as production, sales, finance, accounting, on the other. A true catalyst is not transformed. Neither should management be transformed. It must not be transformed by labor, by ownership, or by government, to reflect, to the exclusion of the others, any one of the factors mentioned. If it is, then the results of management will be just as faulty as the results of chemistry when the catalyzer fails. This fact is all too often disregarded.

POWDER METALLURGY

Physical Properties of Parts Made From Iron Powder

By F. V. LENEL

MORAINE PRODUCTS DIVISION, GENERAL MOTORS CORPORATION, DAYTON, OHIO

PRODUCTS of powder metallurgy may be roughly divided into two classes. The first class would include those products which cannot be made at all by any other method, or at least cannot be made easily, except by powder metallurgy. In this class belong such products as refractory-metal wire and sheet, cemented-carbide tools, self-lubricating bearings, electrical-contact materials, etc. The second class would consist of those products which can be made by conventional methods, such as die casting or machining of wrought or cast metal as well as by powder-metallurgy methods. It is this latter class of products with which this paper is concerned.

It is often possible in powder metallurgy to briquette and sinter a product to the finished size. In this way the cost of machining and the cost of scrap produced in machining are saved. In order to make the powder-metallurgy process competitive, these savings must be large enough to compensate for the increased cost of raw material, that is, powder versus bar stock or casting, and the cost of the powder-metallurgy-processing operations, namely, briquetting, sintering, and sizing. In some cases, where only a semifinished product can be briquetted, the cost of the final machining will have to be added to the powder-metallurgy operations in order to arrive at comparative costs. A complete comparison of costs, based upon the number of pieces to be produced, should also include the cost of tooling for briquetting and sizing, as against the tooling setup for machining by conventional methods. There are usually fewer operations in the powder-metallurgy process, but the cost of the hardened-steel tools needed for these operations is not low. Furthermore, it is of course necessary that the powder-metallurgy products have mechanical properties which will be satisfactory for the service for which they are intended.

Reference will be made particularly to those products which are manufactured from iron powder, and which therefore compete with products machined from steel bar stock, steel forgings, or steel or cast-iron castings. In the past many claims have been advanced with regard to the mechanical properties of such iron parts; and it has been felt throughout the industry that a clarification is necessary as to what mechanical properties can be obtained consistently in large-scale production.

FORMULATING METAL-POWDER SPECIFICATIONS

Because of the widespread demand for specifications for iron-powder parts, the manufacturers of metal-powder products have organized a committee to prepare general specifications for iron parts made from metal powders. The formulation of these specifications has met with problems which are peculiar to the powder-metallurgy process. These difficulties should be thoroughly understood not only by the manufacturer but also by the user of powder-metallurgy products.

In articles made by powder metallurgy, the size and shape of the product has a direct bearing on its mechanical properties. The tensile strength, ductility, hardness, impact strength, etc., of a finished product machined from bar stock are assumed to be the same as those of the stock from which the piece was made. In castings, coupons can be cast together with the casting, the mechanical properties of these coupons can be determined, and in this way representative values for the mechanical properties of the casting can be obtained, although the influence of the section thickness may be quite important and will have to be taken into consideration. In powder-metallurgy products, the effect of size and shape of the finished product upon its mechanical properties is even more accentuated and will be discussed somewhat more in detail to show the reasons for it.

MECHANICAL PROPERTIES

Metal-powder products are made by briquetting metal powders in steel dies and sintering the briquetted shapes in furnaces with controlled atmospheres. After sintering, the products may be further processed by a sizing operation or by sizing and subsequent resintering. For purposes of this discussion, the mechanical properties of the finished pieces may be described as depending upon four factors, as follows:

1 Composition of the powder mixture.
2 Grade of powders used.
3 Temperature, length of time, and atmosphere of the sintering and resintering operations.
4 Density, resulting from briquetting, sintering, and sizing operations.

The first three of these factors have parallels in cast and wrought materials (chemical composition, purity, heat-treatment) but factor (4) is peculiar to metal-powder products. The density is also different from the other factors, because it depends not only upon the processing of the product but also upon its size and shape. This correlation between density, processing conditions, size, and shape of the product, and mechanical properties may be treated under the following headings:

1 How the mechanical properties depend upon the density of the product.
2 How the density depends upon the processing steps.
3 How the density depends upon the size and shape of the product.
4 How the size and shape of the product influence its processing.

1 The tensile strength, impact strength, and hardness, as well as the ductility, of a metal-powder product will increase with increasing density of the product, if the same powder mixture, quality of powder, and sintering treatment are used. Fig. 1, giving the tensile strength, yield point, elongation in 1 in., and hardness for a number of test specimens made from a grade of hydrogen-reduced iron powder and sintered three hours in partially combusted natural gas at a temperature of 2000 F, but having different densities, illustrates the point.

2 The density of a metal-powder product will depend to a certain extent upon the powder mixture, the quality of the powder, and the heat-treatment of the product, but the most important factors influencing the density will be the briquetting pressure used to compact the powder into a coherent piece, and the sizing pressure used in coining or cold-forging the product after it has been sintered. A piece having a given size and

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Contributed by the Production Engineering Division and presented at the Spring Meeting, Davenport, Iowa, April 26–28, 1943, of The American Society of Mechanical Engineers.

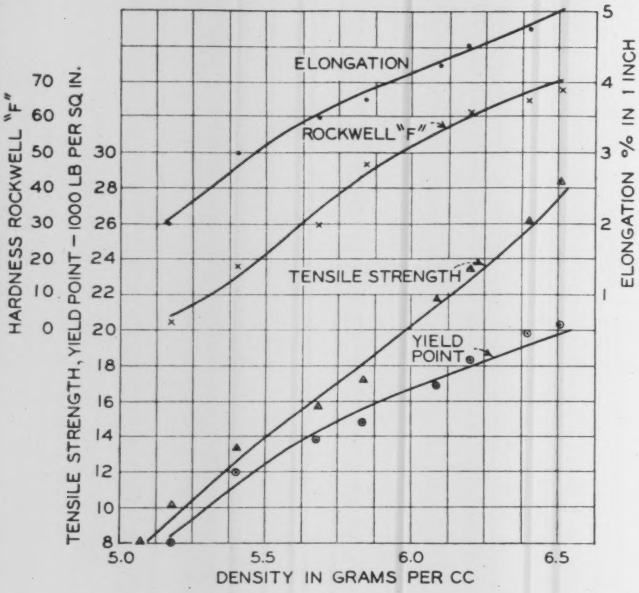


FIG. 1 RELATION OF MECHANICAL PROPERTIES TO DENSITY FOR TEST PIECES BRIQUETTED FROM A HYDROGEN-REDUCED IRON POWDER AND SINTERED 3 HR AT 2000 F

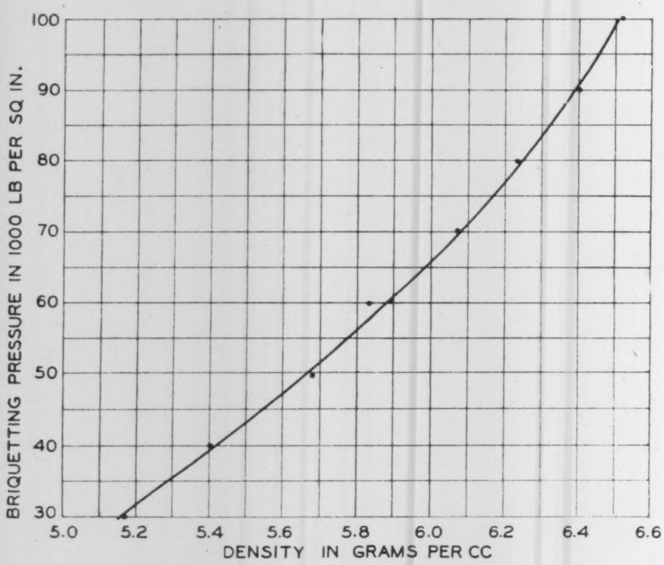


FIG. 2 RELATION OF DENSITY TO BRIQUETTING PRESSURE FOR TEST PIECES BRIQUETTED FROM A HYDROGEN-REDUCED IRON POWDER AND SINTERED 3 HR AT 2000 F

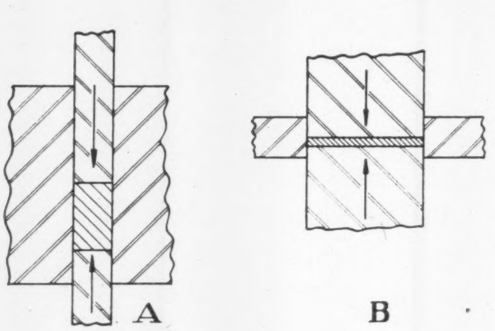


FIG. 3 SCHEMATIC SKETCH ILLUSTRATING LOWER DENSITY OF LONG SLENDER PIECE *A*, AS COMPARED WITH SHORT, THICK PIECE *B*

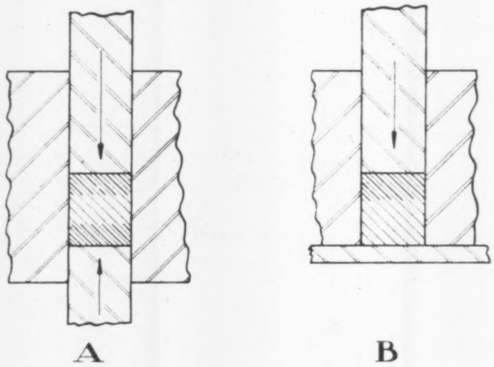


FIG. 4 SCHEMATIC SKETCH ILLUSTRATING UNEVEN DENSITY DISTRIBUTION IN PIECES BRIQUETTED FROM BOTH ENDS *A* AND FROM ONE END *B*

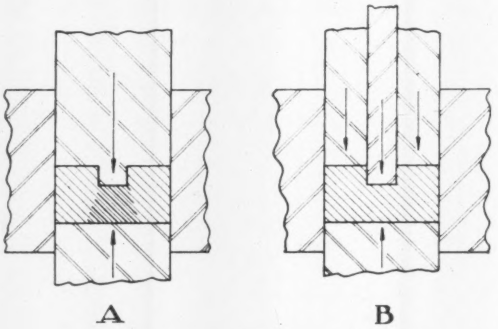


FIG. 5 SCHEMATIC SKETCH ILLUSTRATING UNEVEN DENSITY DISTRIBUTION IN A PIECE WITH NONUNIFORM SECTION WHEN BRIQUETTED WITH A SINGLE PUNCH *A*, AS COMPARED WITH THE EVEN DENSITY DISTRIBUTION IN THE SAME PIECE WHEN BRIQUETTED WITH MULTIPLE PUNCHES *B*

shape will be the denser the higher the briquetting pressure and the higher the sizing pressure. Fig. 2 shows the correlation between briquetting pressure and density for the same set of specimens as shown in Fig. 1.

3 The density of pieces having different shapes and dimensions will be different even if the same briquetting and sizing pressure are used. These differences are due to the fact that most metal-powder products are briquetted only along one axis. Therefore the friction between the die and the powder will influence the density in two ways:

(*a*) With a given briquetting and sizing pressure, pieces which are long and slender in the direction of pressing will be less dense than pieces which are short and thick, Fig. 3.

(*b*) Pieces whose ratio of length (dimension in the direction of pressing) to width (dimension perpendicular to direction of pressing) is large (in general greater than 2) will have an uneven density over their length. If pressed from both ends they will be denser at the ends than in the middle, and if pressed from only one end, they will be denser at one end than at the other, Fig. 4.

Pieces which have a nonuniform section in the direction of pressing (e.g., flanged pieces) may either be made with single punches or with multiple punches sliding relative to each other. If the piece is made with single punches the density will be higher in the short section than in the long section, because of the difference in the rate of compression of the powder. For some applications this difference in density and the corresponding difference in strength, ductility, and hardness is permissible; for other pieces multiple punches are necessary to make the density throughout the section as even as possible, Fig. 5.

4 As explained, a high density may be obtained by using high briquetting and sizing pressures. However, these pressures are limited by the pressure which the briquetting and sizing dies will stand without rapid failure by fatigue or wear.

The permissible sizing pressure and, to a lesser extent, the permissible briquetting pressure will also depend upon the shape of the piece and the design of the die. A punch having a thin weblike section will not stand as high a pressure in pounds per square inch as a solid heavy section. For large pieces, the capacities of the available briquetting and sizing equipment may also be limiting factors. The density which can be obtained in complicated pieces will, therefore, not be as high as it is in standard test pieces. In some cases, the lower physical properties, due to this lower density, may be compensated for by a change in the grade of powder or the sintering conditions, but such changes will of course also alter the cost picture.

THREE CLASSES OF METAL-POWDER PRODUCTS

The foregoing discussion makes it clear why it is not practical to set up specifications for tensile strength, ductility, etc., to be determined on specially briquetted test specimens. The properties of such test specimens would not be representative of the properties of a complicated briquetted piece, even if the same briquetting pressure and sintering conditions were used. Neither is it usually practical to cut tensile or impact specimens from the metal products themselves, because most parts made from powders are too small for cutting test specimens. For this reason, it does not seem advisable to set up general specifications for the tensile properties of metal-powder products. The only specifications for iron parts in actual figures which should be included in a general specification are those for chemical composition and density. In order to grade parts made from iron powder, according to their properties, they may be divided into three types, as follows:

Type A: Materials having mechanical properties similar to common cast iron suitable for applications where the stresses are very low.

Type B: Materials similar to type A, having improved tensile strength, a definite yield point, and a noticeable elongation.

Type C: Materials having mechanical properties approaching ordinary malleable iron, suitable for applications where stresses including impact are moderate.

There would be no sharp lines of demarcation between these various types, and the division into the three types would be for the convenience of the user rather than for any fundamental reasons. The grade of powder used, the briquetting and the sizing pressures, the time and temperature of heat-treatment would determine in what class a particular product would fall, changes in one or more of these factors possibly shifting a product from one class to another. The three types would be identified by their specifications for chemical composition and for density, as suggested in Table 1. The table shows that for parts with better physical properties, namely, higher strength and ductility, an impure product with low density would not be suitable. The purity rises from 95 per cent minimum iron to 98 per cent minimum iron; the density from 5.4 g per cc minimum to 6.5 g per cc minimum.

TABLE 1 CHEMICAL AND DENSITY REQUIREMENTS

Type	Total carbon, per cent	Total iron, per cent	Density g per cc
A	2.5 (Max)	95 (Min)	5.4 (Min)
B	0.4 (Max)	97.5 (Min)	5.8 (Min)
C	0.2 (Max)	98.5 (Min)	6.5 (Min)

Type A would include parts which contain up to $2^1/_2$ per cent carbon. The carbon may be added to the powder mixture in the form of graphite and would combine with the iron during the sintering operation. Such carbon-containing iron-powder products are harder and stronger than straight iron products, but they are also more brittle.

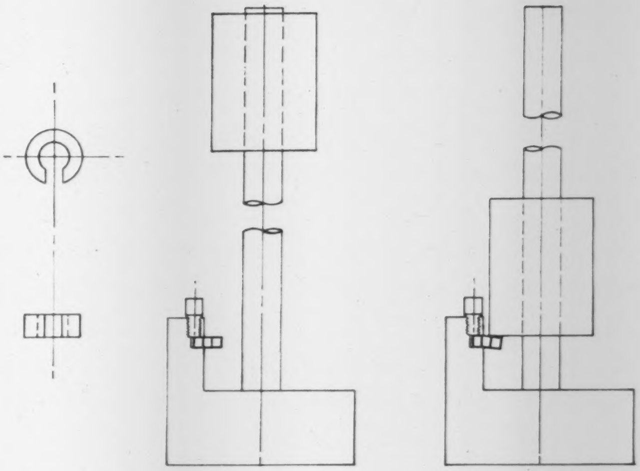


FIG. 6 PIECE WHICH MAY BE MADE BY POWDER METALLURGY, AND A FIXTURE DESIGNED TO TEST ITS SHOCK RESISTANCE

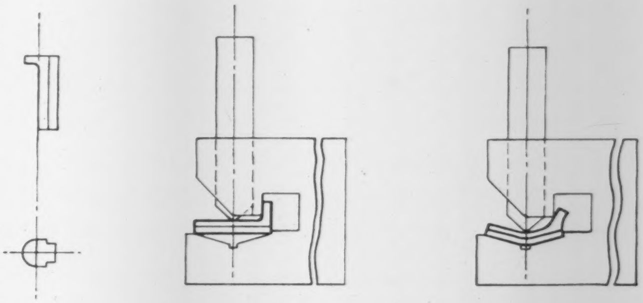


FIG. 7 PIECE WHICH MAY BE MADE BY POWDER METALLURGY, AND A FIXTURE DESIGNED TO TEST ITS DUCTILITY

STRENGTH TESTS FOR INDIVIDUAL PARTS

Because a general specification necessarily has to be broad, it will be necessary to develop detail specifications for individual parts. They should be set up after performance tests on the parts have shown that they are satisfactory for the application. The detail specifications should furnish a check on the uniformity of the production and, whenever possible, on the performance characteristics of the tested product. Such tests are as follows:

1 Crushing, radial or shear strength.

2 Bending or impact drop test.

3 Hardness at one or more specified points of the piece or hardness variation over the entire piece.

Static strength tests would be suitable for pieces where no particular impact resistance is needed, for instance, oil-pump gears may be so tested. The gear is held in a fixture and the load required to break off one of the teeth is determined. Hollow cylindrical pieces may be tested by a radial break test; the piece is crushed between two flat plates and the load is measured when failure occurs.

When a certain amount of shock resistance is required in a piece, a bending or an impact test should be devised. Tests have shown that impact strength and ductility in powder-metallurgy products parallel each other. In other words, a material which does not show any elongation in a tensile test, or no bending in a bend test, will usually be quite shock-sensitive. On the other hand, a material which has a fair amount of ductility will not break so easily under a sudden blow. Fig. 6 shows such a piece where shock resistance is required, and the testing fixture designed to test the piece. The piece is clamped in the vise in such a way that one side of the slot is flush with the edge of the vise, with slightly more than one half of the piece protruding from the vise. The specification would read that a specified weight dropped from a specified height should not fracture the piece and that the same weight dropped from some lower height should not cause a crack in the piece.

Fig. 7 shows another specimen in which a certain amount of shock resistance is needed. This piece is briquetted with the long section in the direction of pressing, pressure being applied both from the top and the bottom. As previously explained, this piece will show some difference in density along the long section. It will have the lowest density and, therefore, the lowest strength and ductility in the middle of the long section. The test fixture is so designed that the piece is bent to a specified degree at this, its weakest point; the idea being that if the piece does not fracture at this point it will be satisfactory throughout. Simultaneously, the point where the flangelike section and the long section join is tested by bending the flangelike section. In this case, the actual piece is not expected to be bent in service but it will have to withstand a certain amount of shock. As previously outlined, the bend test will also give a good indication of the resistance to shock of the piece.

Both the strength tests and the tests for shock resistance described are destructive tests and, therefore, only a small percentage of pieces can be tested. However, in many applications no nondestructive test would be satisfactory.

HARDNESS TESTING

A hardness test of the indentation type would be such a nondestructive test. Indentation hardness tests, like Brinell or Rockwell, are very convenient and may be quite useful for powder-metallurgy products, but it is necessary that whoever specifies and applies the test understand the mechanism of an indentation test on porous material. The resistance to indentation, which is measured, is a function not only of the chemical composition and the microstructure of the tested piece but also of its density. The lower the density, or in other words, the less material there is to resist the deformation, the further will the indenter sink into the material and the lower will be the reading. Two pieces which show identical hardness readings may therefore have entirely different properties. One may be low in combined carbon but high in density and therefore quite ductile and shock-resistant. The other may have a high combined carbon content but a low density and would, therefore, be quite brittle and shock-sensitive.

The influence of density on the indentation-hardness reading must also be considered when the abrasion resistance of a material is to be evaluated. The abrasion resistance depends much more upon the microstructure of the material than upon its density. For instance, a piece made of iron powder and containing sufficient combined carbon may be heat-treated and may then be fully martensitic. Such a piece will be file-hard, but the hardness reading on the Rockwell C scale may be only 30. The peculiarities of the indentation-hardness test on powder-metallurgy products should always be kept in mind and particularly so when the hardness of a product made from powder is compared with the hardness of a product made in the conventional way.

For the reasons just outlined, the tensile properties of products made from powder should not be included as part of a general specification; however, such properties can be and have been measured. The values shown in Table 2 were determined on special subsize specimens. Typical values are given for the three previously suggested types of material.

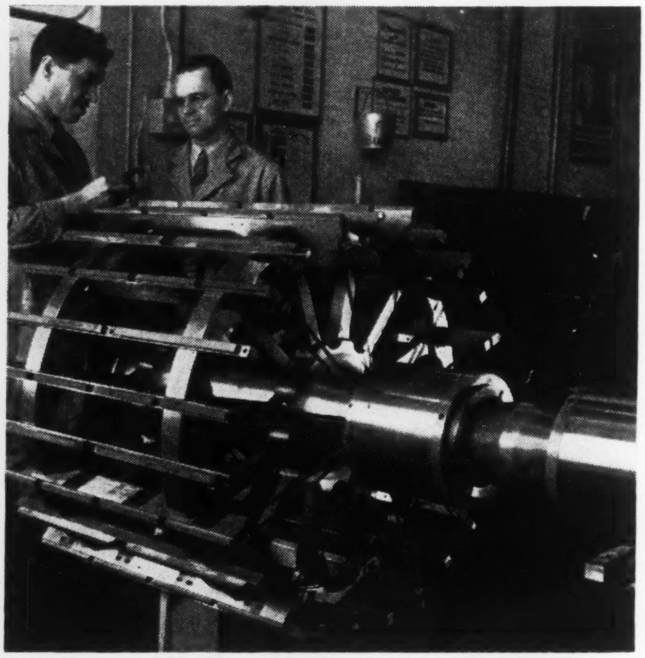
It must be admitted that the values given in Table 2, which are purposely on the conservative side, are not very impressive. Under laboratory conditions, it has been possible to obtain much superior properties and some such values have been widely publicized, but at the present time no large-scale production technique has been developed which would permit the manufacture of parts from iron powder with high strength and high ductility at a competitive cost. The main difficulty lies in achieving satisfactory ductility and impact resistance, while it is much less difficult to obtain higher strength and high hardness by proper heat-treatment. These heat-treated materials are not specifically included in Table 2; they are rather brittle and cannot be used in any application where they have to withstand shock.

TABLE 2 TENSILE PROPERTIES

Type	Tensile strength, psi	Elongation, per cent in 1 in.
A	15000	$\frac{1}{2}$
B	25000	3
C	35000	7

WIDE APPLICATION TO SMALL-ARMS PARTS

There exist, however, numerous applications where the mechanical properties of iron-powder products are quite adequate for this purpose. After all, in many components of small arms or of expendable munitions, to mention only two fields which are at present in the foreground of interest, an accurate configuration is much more important than high mechanical properties. Many of these components are at present made from low-carbon steel because that is the cheapest and most convenient material available. However, that does not mean that the physical properties actually needed are those of low-carbon steel. These are the applications where powder metallurgy is believed to have a field, if by this method a part can be made at a competitive cost and with a saving in machine time and in bar stock. The metal-powder-parts manufacturer and the user of the parts should co-operate in selecting suitable applications and in setting up detail specifications which will insure the quality and uniformity of production.



THE LARGEST HONE-ABRADING TOOL EVER MADE

(Recently shipped by Micromatic Hone Corporation to a war contractor. This hydraulically controlled hone is $41\frac{1}{2}$ in. diam by, approximately, 63 ft long over-all and weighs approximately 6500 lb. It is intended for use in a bore 40 ft long and it is anticipated that about $\frac{1}{16}$ in. of stock on diameter must be removed to clean up the bore. This will amount to more than 550 lb of metal to be removed by the hone-abrading process. The tool is used in a special horizontal honing machine designed and built by the Barnes Drill Company.)

AIRCRAFT ENGINES *on* *the* PRODUCTION LINE

By H. E. LINSLEY

WRIGHT AERONAUTICAL CORPORATION, PATERSON, N. J.

THREE years of war production have created a revolution in manufacturing methods in the aircraft-engine industry such as could not, in all probability, have been achieved in a quarter of a century of peacetime. During the decade prior to the first world war, the manufacture of aircraft was not even included in the general picture of American industry, confined as it was to the individual efforts of a few supposed "crackpots." With the coming of that war, and the realization of the importance of aircraft, a new industry was born, an industry destined to dominate the American scene. With the close of the war, this new industry suffered an almost complete collapse, and it was only the persistence and idealism of a few enthusiasts which kept it alive.

With the passing years the public gradually accepted aviation, but even as late as 1938 manufacture was on virtually a custom-built basis. The Wright Aeronautical Corporation, for example, which had been in business ever since the founding of the original Wright Company by the brothers Wilbur and Orville Wright, was building its engines in lots that rarely exceeded 50, and were frequently as small as 2 or 3. Under such conditions, therefore, it was only natural that standard conventional machine tools should be used. Furthermore, since engines were made to suit individual customer requirements, there were so many different models and so many changes in design that it would have been entirely impractical to attempt to make use of special single-purpose machines.

STANDARDIZATION OF ENGINES MAKES PRODUCTION LINE POSSIBLE

With the outbreak of the present war, however, there came a sudden demand for thousands of engines of a single type, and it then became feasible to consider the possibilities of line production. The outstanding proponent of mass production was, of course, the automobile industry, and it was logical that we should look to it for information. Not that there was any question of making use of actual automotive production tools, since, apart from the fact that both are conventional four-cycle internal-combustion engines, there are no points of resemblance between the aircraft engine and the automobile engine.

The automobile engine, for example, is a solid rigid mechanism, built largely from cast iron, and in which weight is an advantage; indeed most such engines weigh about 6 or 7 lb per hp. The aircraft engine, on the other hand, particularly the radial air-cooled type commonly in use, is built of lightweight metals and high-strength alloy steels of light section in order to maintain a weight of 1 lb or less per hp. Consequently, tools and processes were of an entirely different nature from those required for aircraft work. Nevertheless, from the automobile industry we were able to get ideas on materials handling and production processes which we could adapt to our own product.

The change from low to high production was not achieved immediately. Until the present energency arose, there had been no demand for special equipment, and consequently there was little or none available. Furthermore many of the machines we planned to use required as much as a year to design and build. One of the first steps, therefore, was to obtain such special equipment as could be made or adapted in a comparatively short time and, with the help of this and large numbers of standard machines, get our schedules under way. The accompanying illustrations show a few examples of this transition, and, for purposes of this paper, the production tools shown will serve as a representative cross section of the types of equipment now in general use.

HIGH-SPEED MACHINES IMPROVE ACCURACY

Once these machines have been observed in operation, the tendency is to take them as a matter of course. Inevitably the question arises: Why, if, for example, twelve operations have been combined into a single machine, have not a thirteenth and fourteenth been incorporated? It must be borne in mind, however, that these machines were not created over night. They are the fruit of weeks and months of effort and have involved overcoming what seemed impossible obstacles. Not the least of these was the question of precision. At first, there was considerable doubt as to whether automatic equipment could be operated at high speeds and still hold the very close limits required. Experience, however, has shown that, contrary to first expectations, limits can be held even closer than on standard tools and that there is a substantial reduction in the amount of scrap. This can be attributed to the massive construction which eliminates vibration and to the fact that single-purpose design permits the use of extremely heavy spindles and a minimum of overhang. The use of electrolimit switches and hydraulic feeds is also a contributing factor.

It is not felt, however, that the ultimate has yet been reached. Indeed, it may be said that only the surface has been scratched, in so far as automatic equipment is concerned. Already the Greenlee machine used for cylinder heads has been improved to the point where several milling operations are included, and where the parts are inverted on their trip through the machine to permit working on surfaces which cannot be reached from the outside.

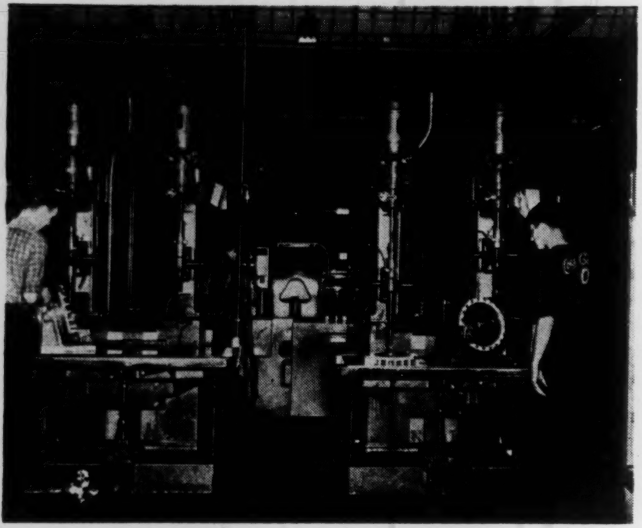
In designing machines of this type, there is one factor which must be kept in mind and which frequently acts as a controlling or limiting agent, that is, the necessity of retaining sufficient flexibility so that design changes in the parts will not necessitate scrapping or costly major changes in the equipment. This precaution must not, of course, be carried too far. For example, one would not design a machine to operate on the crankcase of a 7-cylinder engine and, at the same time, make provisions for the extremely remote possibility that this might someday be changed to a 9-cylinder engine. On the other hand, many such machines can be and frequently are designed to handle two or more different parts, particularly when the production requirements on one part alone are not sufficient to justify installation of the equipment.

The Greenlee transfer machine used by the Wright Aeronautical for the manufacture of cylinder heads is an example of this dual-purpose equipment. On the 14-cylinder engine, the heads for the front-row cylinders are different in some respects from those for the rear row, and the machine is equipped to handle both types. Many of the tools are common to both, but the special ones may be cut in or out by the simple turn of a switch.

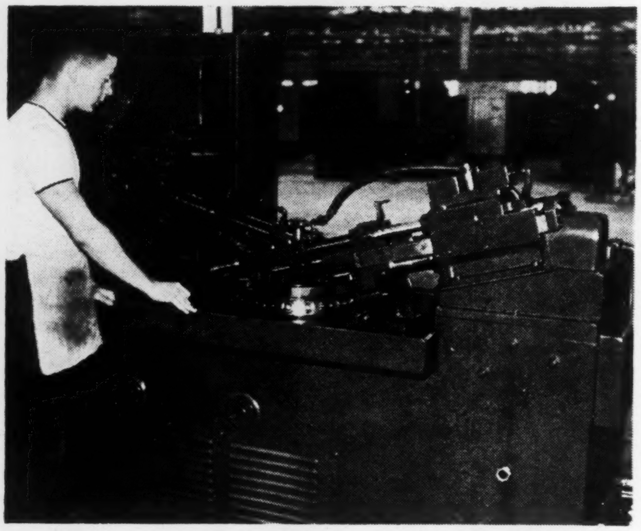
Contributed by the Aeronautical Division and presented at the Spring Meeting, Davenport, Iowa, April 26–28, 1943, of The American Society of Mechanical Engineers.

SCORES OF SINGLE-SPINDLE DRILL PRESSES ONCE NEEDED FOR DRILLING, REAMING, AND TAPPING HOLES IN A CYLINDER HEAD

GREENLEE MACHINE AUTOMATICALLY DRILLS, REAMS, TAPS, CHAMFERS, AND SPOTFACES ALL HOLES IN CYLINDER HEAD



DRILLING AND REAMING THE ANGULAR OIL HOLES IN REDUCTION-GEAR CARRIER-RING TRUNNIONS WAS ORIGINALLY A SINGLE-SPINDLE OPERATION WITH THE PART HANDLED ON AN ANGULAR FIXTURE EQUIPPED WITH A MANUAL INDEXING DEVICE

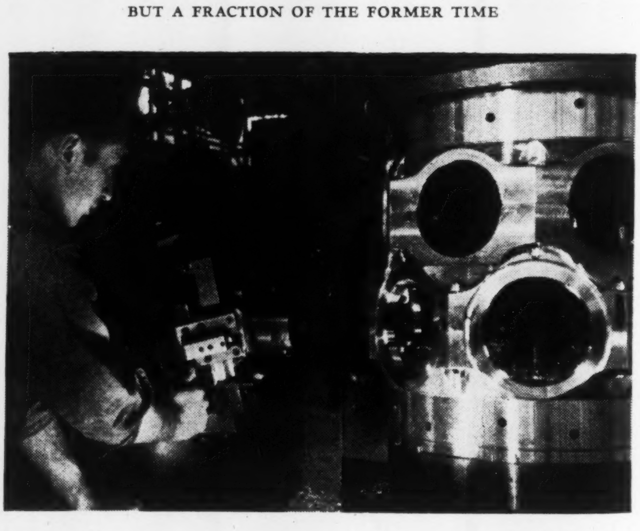


THIS AUTOMATIC FOUR-SPINDLE MACHINE DRILLS AND REAMS THE ANGULAR OIL HOLES IN THE REDUCTION-GEAR CARRIER-RING IN BUT A FRACTION OF THE FORMER TIME

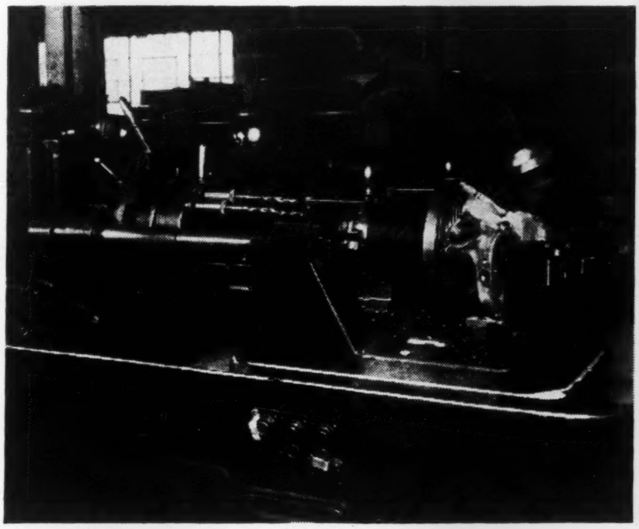
This type of equipment is naturally quite expensive, and careful studies as to adaptability, machine load, and the like, should be made before deciding to purchase. Such studies by the author's company, for example, revealed in almost every case that in first cost alone special machines would effect a very substantial saving over the large number of standard machines which would be required to give an equal production, without taking into account the continuous day-by-day savings in productive man-hours.

CONVEYER EQUIPMENT ALSO ESSENTIAL TO HIGH PRODUCTION

Machine tools alone are not the total answer to the problem of increased output; proper material flow is of at least equal importance. A complete conveyer system now maintains an uninterrupted stream of parts from machine to machine, saves very substantial floor areas which would otherwise be required for the storage of parts in process, and avoids the bottlenecks which are so apt to occur when reliance is placed on a shop trucking system. Aisles between machines can be made narrower since no provision need be made for the storage



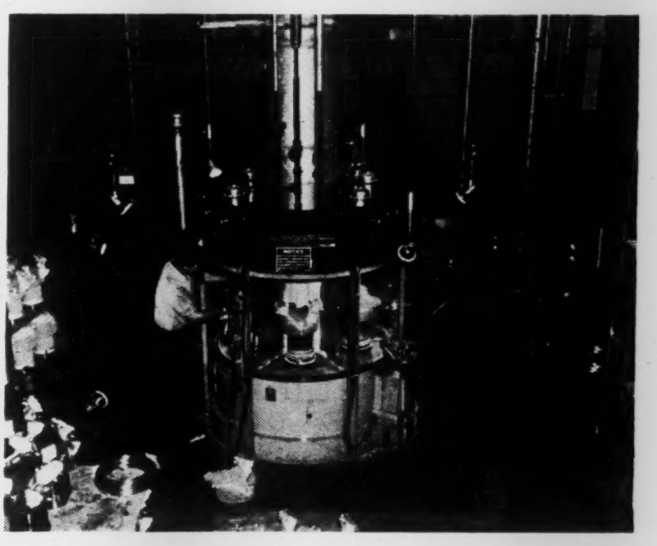
THE CYLINDER DECK PADS OF CYCLONE CRANKCASES WERE BORED, FACED, AND CHAMFERED ON A SPECIAL PLATEN-TYPE TURRET LATHE UNTIL ABOUT TWO YEARS AGO



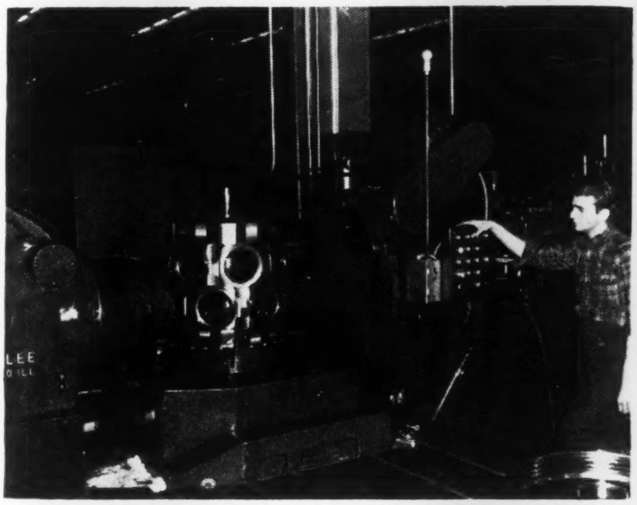
CYLINDER-BARREL-FLANGE HOLES FORMERLY DRILLED AND REAMED ON TWO MULTISPINDLE MACHINES, ONE PIECE AT A TIME

MODERN METHOD OF DRILLING CYLINDER-BARREL-FLANGE HOLES ON A 40-SPINDLE 5-STATION AUTOMATICALLY INDEXING MACHINE

PREWAR METHOD OF METALLIZING CYCLONE CYLINDERS BY HAND OPERATION PERFORMED ON A ONE-AT-A-TIME BASIS



QUANTITY PRODUCTION METHODS NOW IN USE AT WRIGHT AERONAUTICAL PLANTS TO MEET WARTIME DEMANDS BROUGHT ABOUT INSTALLATION OF THIS SIX-STATION FULLY AUTOMATIC METALLIZING MACHINE



DOUBLE-HEAD MACHINE NOW AUTOMATICALLY BORES, FACES, AND CHAMFERS THE CYLINDER DECK PADS OF WRIGHT CYCLONES IN LESS THAN A QUARTER OF THE FORMER TIME

of material at machines. In the present emergency, the Wright Aeronautical Corporation, like most other employers, has turned to woman power, and here again conveyers have been most effective, eliminating the stooping and lifting inevitable when parts are stored on skids at the machines.

One of the greatest contributions to increased production has been the installation of a powered conveyer on the assembly line. This is of the reciprocating type and consists of a cable running in a shallow trench in the floor. It is fitted with a series of hinged dogs spaced at the proper intervals to engage each engine stand. At the forward end is a 5-ton electric winch controlled by an automatic timer which at the appropriate time moves the whole line forward one station. The return stroke is effected by a 1-ton winch at the rear end.

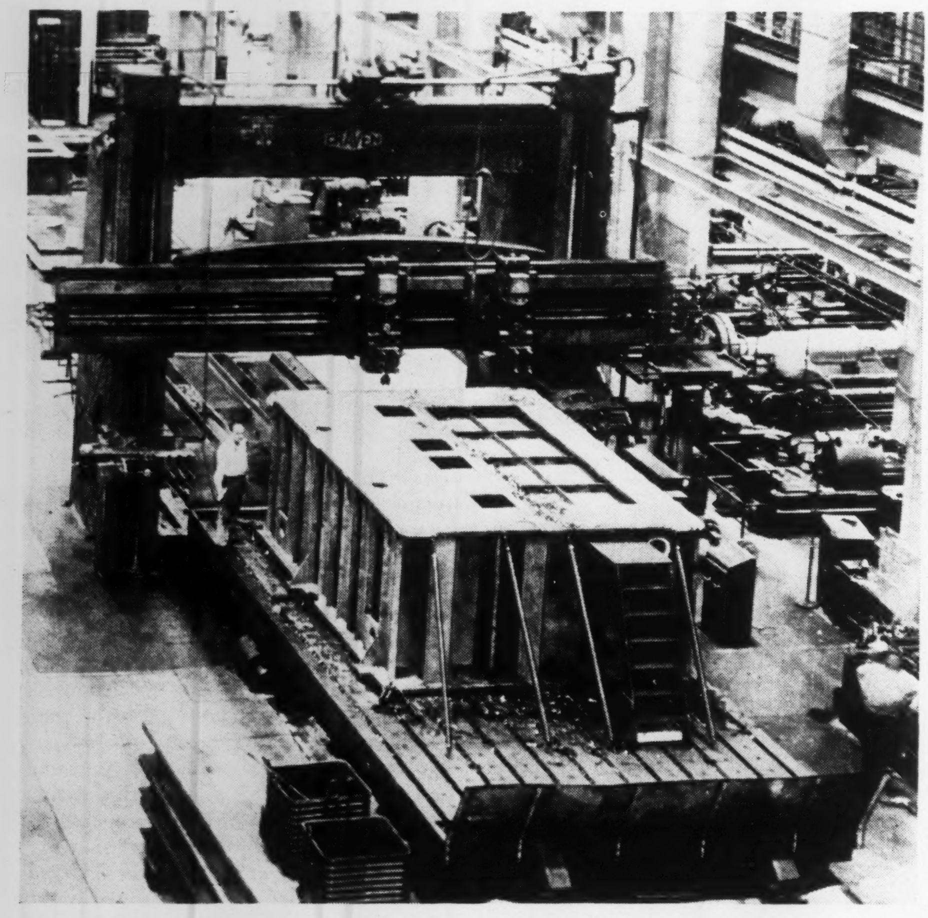
Considerable difficulty was experienced in breaking down the various assembly operations into equal increments, but this was finally accomplished and resulted in a very substantial reduction in the assembly time. Under the old-style spot assembly, it was necessary to train each employee to know where and how each separate unit of the engine was to be assembled. Under the present system, an employee is required to be familiar only with the particular part or parts assembled at his station. Subassemblies are similarly built up on progressive lines, so arranged as to terminate at exactly the point on the main line at which they are required. In the case of the heavier units, a conveyer delivers the parts to a position where they can be picked up by a pneumatic hoist located directly over the assembly point.

After the engines have undergone their first or green test run, they are disassembled on a similar conveyer line, the individual parts being placed on trays suspended from a conveyer chain. This carries them through a wash machine in which they are sprayed with solvent from high-pressure nozzles, rinsed, and dried by compressed air. The conveyer then passes the ends of a series of benches where the inspectors remove the particular parts to which they are assigned, inspect them, and forward them to the final assembly line similar to the green line.

TRANSLATING PRODUCTION KNOWLEDGE TO PEACETIME TASKS

In these days a great deal is heard concerning the "production army." It is indeed an army and an important one, since it must produce the weapons by which final victory can be achieved. It is made up like any other army; its officers are the engineers, representing many branches, mechanical engineers, production engineers, civil engineers, tool engineers. Its soldiers are the men and women at the bench and the machine. Some of their achievements are simply amazing. For instance, the author recently heard of a former manufacturer of slot machines who is now producing shell fuses. In his peacetime manufacture, it is doubtful whether he had ever heard of tolerances of 0.001 in. much less 0.0001 in. Today, he is producing, in endless quantities, precision parts upon which the lives of men depend and which must be accurate within the very closest limits. This case could be multiplied endlessly. It is safe to say that it will have a very far-reaching influence on the world of tomorrow. It is inconceivable that there could ever be any return to the old ways of doing things. This understanding of the importance of close tolerances, and more particularly the development of high-speed automatic machines capable of holding them, will undoubtedly have a vital bearing upon the quality and price of future peacetime products.

Noteworthy as the achievements of the engineering profession have been in this wartime production battle, they are as nothing to what must be achieved in the greater battle which will follow the ending of the war. The task of reconverting industry to its peacetime pursuits rapidly and efficiently, and of implementing the technological gains of the war years in terms of domestic production, will constitute a mighty challenge to the engineer. To this effort the aircraft industry will be able to contribute greatly in terms of production methods and machines.



BRITISH MACHINES HELP PRODUCE PROPULSION EQUIPMENT AT GENERAL ELECTRIC

(Five huge metalworking machines, shipped from Great Britain early in 1942, are helping to produce propulsion sets at a New England General Electric plant. The machines were shipped from Great Britain to a new General Electric plant when it was impossible to get such apparatus from American sources in time to meet production requirements. Of the five machines, two are planers, used to machine gear casings weighing up to 20 tons each. One of these planers is about 70 feet long by 30 feet wide by 20 feet high. Three large casings can be machined on this planer simultaneously. The other three machines are hobbers which are used to cut the teeth in large low-speed gears that transmit power for driving the propellers. Some of these gears weigh as much as 35 tons.)

Effect of SCREW THREADS *on* FATIGUE

A Review of the Literature

By S. M. ARNOLD

BELL TELEPHONE LABORATORIES, INCORPORATED, NEW YORK, N. Y.

THE failure of metal parts under repeated loads, at stresses well below those known to cause failure under static conditions, has been the subject of intensive study for many years.

One of the most familiar of the early investigations was that of Wohler (1),[1] carried on over several years between 1850 and 1870. Among the phenomena considered by him was the profound effect of surface discontinuities on endurance strength. From this time on, increasing attention has been given to the effects of "stress raisers," such as shoulders, fillets, notches, grooves, and screw threads. The part played by threaded members has been recognized as demanding more attention because of the rapidly increasing requirements for higher stresses and speeds, resulting in the likelihood of frequent fatigue failures. This is of particular concern in the field of aviation where the failure of even a minor structural element may mean the loss of human life as well as material loss.

The following review is concerned primarily with those investigations covering the endurance testing of threaded members and screwed joints, and was made in an attempt to segregate information on this particular phase of the subject from the more general data on metal fatigue.

AMPLIFICATION OF PUBLISHED DATA REQUIRED

Throughout the entire period of metal-fatigue testing, there has been a general failure to recognize that the "fatigue strength" as determined for a particular specimen, is not an inherent property of the specific material but is defined by the dimensions of the piece as well as its case history, including heat-treatment and method of preparation. Due to this lack of appreciation of the necessity for establishing the conditions of the test, many of the data in the literature are of qualitative interest only and should not be compared with the results of other investigators. Some of these published values will be given in this review, but they should not be considered quantitative for other than the specified conditions.

Thus in assessing the results of specific studies, the effect of size of test specimen is one of the factors which must be considered. This effect has not been definitely established (118, 150, 158). Peterson (42) found no appreciable size effect in a 0.42 carbon steel for specimens from 0.05 to 1 in. diam. However, it is believed that where there are stress raisers present, the size is of more importance than in the case of smooth specimens (94). In one investigation, notch sensitivity was not found until the diameter of the test specimen reached 10 to 20 mm (110). In some rotating-cantilever-beam fatigue tests on three types of steel, the endurance decreased with increasing diameter up to 0.5 in. Above this, up to a diameter of 2 in., there was little change in endurance strength. This is in line with other data in which the smaller specimens were found to exhibit generally a higher fatigue strength, but a limiting size is reached above which there is little change (98, 128, 164). It is claimed that if all the dimensions are changed in proportion, including those of section changes and notches, the fatigue strength of a larger member could be predicted from the data on a smaller test specimen (122, 123).

Another factor to be considered is the number of stress reversals necessary to establish the fatigue limit. Failure to continue the test for a sufficient number of operations has influenced some of the published data. In a table covering a number of nonferrous materials, Moore (15) indicated the wide variation in the minimum number of cycles required to establish the endurance life.

A difficulty peculiar to testing threaded parts is the tendency for the piece to fail at the end of the thread. Such a failure should be ascribed to the notch effect of the first thread rather than to failure in the thread (40). Prevention of this type of failure will be considered later.

The method used to determine fatigue strength also may be questioned. However, after reviewing several sets of data, it is believed that there is no great difference in the way a given metal is affected by a stress raiser under the different methods of testing (101, 167). Similar conclusions are reached as to the notch sensitivity of a metal regardless of the test method. Thus, the torsional fatigue strength may be affected less than the flexural fatigue strength by some discontinuity. However, provided repeated torsion tests place the specimens in the same order as other types of endurance tests, evaluation of methods for decreasing stress concentration can be made by any of the test methods.

Again, the method of manufacture must be considered. In many of the early investigations this information was not included in the published data (154). As will be shown later, the method of producing the thread and the length of the threaded part are factors which greatly influence the endurance life (93, 112, 154).

EFFECT OF GROOVES AND THREADS ON ENDURANCE STRENGTH

Shortly after the deleterious effect of a circumferential groove on fatigue strength was noted, specimens with a series of grooves, and with a helical groove in the form of a thread were studied (3, 5, 21). Thus Stanton and Bairstow (3), in repeated-tension-compression tests, found that a Whitworth screw thread reduced the endurance strength of several ferrous materials 30 per cent or more.

It was also shown that a single circumferential groove caused 2 or 3 times as much reduction in fatigue strength as did a continuous helical groove of the same contour. As an indication of this difference in effect, the results of a rotating-beam endurance test on a medium-carbon steel are given in Table 1.

TABLE 1 RESULTS OF ROTATING-BEAM ENDURANCE TESTS ON MEDIUM-CARBON STEEL

		1/4 in., 28 threads per in.		3/8 in., 24 threads per in.	
	Plain	Notch	Thread	Notch	Thread
	51000	12000	43000	21000	37000
Ratio of notched endurance to endurance		0.24	0.84	0.41	0.73

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[1] Numbers in parentheses refer to the Bibliography at the end of the paper.

Here, the effect of a single groove was compared with that of a continuous thread, both threads conforming to the contour of a U. S. Standard screw thread. The values given are the fatigue strength in pounds per square inch (21).

CONCENTRATION OF STRESS

Numerous attempts have been made to calculate the stress concentrations in the vicinity of such notches, including threads, and several methods have been adopted. Among these methods might be mentioned mathematical (4, 20, 121, 134), photoelastic (68, 126, 156), soap film (6), sensitive extensometric (151), and there have been others (8, 18).

While agreement between the various results is often reasonably close, it has been found that the actual notched endurance strength is much higher than that expected from the calculated results (12, 15, 16, 17, 20, 101, 106, 120, 124). In endurance tests on carbon and alloy steels, the actual endurance strength was found to be reduced to a value of 0.5 to 0.8 instead of to the anticipated value of 0.3. In other rotating-beam fatigue tests, the stress raiser only increased the stress concentration $^1/_3$ of that calculated (17, 124).

Explanations that have been offered concerning the disagreement maintain that either (*a*) there are many small cracks or flaws in even the highest-quality material so that there is not a proportionate degradation resulting from an external notch, or (*b*) there is a redistribution of stress due either to slippage along cleavage planes or plastic flow at the most highly stressed areas. In either case calculated stress concentrations would be invalid, as linear stress distribution from neutral axis to outside fibers is assumed (8, 11).

As an empirical guide for estimating the stress, Moore and Henwood (106) suggest that for bolts and studs subjected to repeated tensile stress, a safe estimate of the stress at the root of a thread would not be P/A but $3P/A$ for ordinary steel, and $4P/A$ for heat-treated alloy steel, where A is the area in square inches at the root of the thread and P is the load in pounds.

METHOD OF MANUFACTURE

It is necessary to consider the method of manufacture as this greatly influences the fatigue strength. Thus a cut thread has a considerably lower endurance than a rolled thread.

Smith (154) considers three manufacturing methods, (*a*) cut threading, (*b*) roll threading on single extruded wire, (*c*) roll threading on double extruded wire.

In method (*b*) the wire is extruded to the pitch diameter. Dies roll the thread, depressing part of the steel to form the root and forcing the remainder up to make the top of the thread. In method (*c*) the wire is extruded to the outside diameter and then extruded to the pitch diameter. The threads are rolled on the reduced wire.

Screws of low-carbon steel formed by each of these three methods were subjected to rotating-beam endurance tests. Table 2 gives a summary of the findings.

TABLE 2 SUMMARY OF ROTATING-BEAM ENDURANCE TESTS ON LOW-CARBON-STEEL SCREWS

Type specimen	Ultimate strength, psi		Endurance limit, psi	Ratio of endurance limit to ultimate strength, per cent	
	Wire	Specimen		Wire	Specimen
Cut thread.........	89300	90000	27000	30.3	30.0
Single extrude roll thread.......	89300	99700	33000	37.0	33.1
Double extrude roll thread.......	77400	99600	33000	42.6	33.1

Staedel (93) pointed out that screws with threads rolled on after heat-treatment have a much higher fatigue strength than screws with cut threads or with threads rolled on before heat-treatment. In other words, heat-treatment will not increase the fatigue strength of threaded parts (105).

In this connection, it must be remembered that while the fatigue strength of a smooth steel part can be increased by heat-treating and hardening, the notch sensitivity is likewise increased where there are notches such as threads present, so that the net result may actually be a lowered endurance strength.

One alternative is the use of an 18-8 type of steel, whose notched endurance may actually be higher than that of an unnotched specimen due to work hardening of the base when cutting the groove (149).

Cazaud (107) cautioned that where threading had to be done before material was quench-hardened, a final reheating was essential to relieve the quenching stresses in the threaded part. This is brought out in Table 5, where the beneficial effect of tempering can be seen.

CHOICE OF MATERIAL

In the selection of a material to be used for a threaded part, the notch sensitivity must not be overlooked. There has been considerable disagreement concerning the advantage of alloy steels over plain-carbon steels in this respect, as well as to the relative merits in so far as endurance strength is concerned (28, 108, 118, 127).

Ludwik (43) and Moore and Henwood (106) found that, in general, alloyed steels were more notch-sensitive than carbon steel, while in Mailänder's study (111), the notch sensitivity of carbon steels was slightly higher than that of alloyed steels of the same fatigue or tensile strength. Hempel (135), on the other hand, found that in repeated tension-compression and in bending endurance tests, carbon steels were less sensitive than Cr-Ni steels while, for repeated torsion, the reverse was found to be true.

As indicative of the fact that our usual conceptions of ductility do not apply in the case of fatigue resistance, a number of authors have found that cast iron is relatively insensitive to notches. On the other hand, annealed copper and aluminum alloys have been found to be very notch-sensitive (22, 23, 29, 145, 161). Thus it was found that a circumferential rounded groove reduced the rotating-beam endurance strength of steels 27 to 42 per cent, and that of annealed copper 40 per cent, while that of cast iron was reduced only 3 per cent.

Whether the consideration of "damping capacity" should influence the choice of material is debatable. Heydekampf (54) has defined damping capacity as the amount of work dissipated into heat by a unit volume of the material during a completely reversed cycle of unit stress. He believes that a material of higher damping capacity is less notch-sensitive. On the other hand, Brophy (71), from his studies on five steels, concluded that damping capacity was not directly related either to notch sensitivity or to fatigue strength. Other authors have disagreed as to the relationship between endurance and damping (116, 117, 167), and as yet this matter has not been definitely settled.

Corrosion due to environment also should be considered in determining the material for the screw stock (21, 120). Parts made of light metals may have their endurance strength reduced as much as 40 per cent, whereas copper alloys, such as brass and bronze, are much less sensitive (55).

INFLUENCE OF COMPOSITION OF SUFACE LAYER

It is generally agreed that a decarburized surface layer results in a decrease in endurance strength. Bretney (142) noted a decrease of 50 per cent as a result of such a layer. Conversely, both casehardening and nitriding have been employed to increase fatigue strength (104, 115, 119, 120). It is important, however, that the casehardening be done after the piece is notched, otherwise a decrease in endurance up to 50 per cent may be found (143). This is also indicated in some work on Ni-Cr-Mo steel where the repeated torsion fatigue strength was increased from 6.4 to 18.5 tons per sq in. by carburizing after, rather than before, notching (136).

EFFECT OF SURFACE COATING AND ANODIZING

Metals such as chromium, nickel, cadmium, and zinc are often electrodeposited on threaded parts to improve the appearance or increase the life of the part in a corrosive environment. The plated coating is often left in a highly stressed condition and may initiate fatigue-cracking. In order to prevent a decrease in the endurance of the part, the plating procedure should be so adjusted that the deposited metal is left in an unstressed condition (40, 70, 120).

Illustrating the effect of an improperly deposited coating, Lea (120) noted that in one case nickel plate reduced the rotating-cantilever-beam endurance more than did a V-groove of the same depth.

Chromium plating has reduced the fatigue strength of a steel as much as 30 per cent, probably because of the known absorption of hydrogen during plating causing embrittlement. Heating the plated part helps only slightly. The authors Wiegand and Scheinost claim that in the case of rotating highly stressed parts, a hard chromium plate should not be used (144).

Zinc is probably used more widely than any other metal as a surface coating. When applied to steel by hot-dipping, there is evidence that the formation of the intermediate zinc-iron alloy layer results in a reduction of the fatigue strength (39, 45). On the other hand, an electrodeposited zinc coating does not affect the endurance strength. Thus while a hot-dipped zinc coating reduced the rotating-beam endurance of some carbon steels as much as 42 per cent, an electrodeposited zinc film had a very slight beneficial effect (45, 83).

Anodizing, carried out in the processing of many aluminum parts, is not recommended for aluminum-alloy screws subjected to repeated stressing (141).

EFFECT OF THREAD CONTOUR

Based on observed differences in endurance found with notches of different radii, variations caused by changes in the contour of a screw thread might be expected. Several investigators have compared the Whitworth thread (with a rounded root) and the U. S. Standard thread (with a truncated V-profile).

In repeated cantilever bending, a single circumferential groove of the contour of a Whitworth thread reduced the endurance strength of a steel from 29,500 psi to 15,000 psi, whereas that corresponding to a U. S. Standard thread reduced the fatigue value to 13,500 psi.

A die-cut Whitworth thread was compared under repeated tension with a U. S. Standard thread, using a medium-carbon steel and an S.A.E. 2320 steel (106). As can be seen in Table 3, appreciable differences were found.

Another comparison of the Whitworth with the U. S. Standard thread was made by Hall by means of polarized light and transparent models, the "photoelastic method" (69). He found that when models of the respective threads were subjected to stress, the maximum stress developed in the U. S. Standard thread was approximately 40 per cent greater than that in the Whitworth thread.

Comparing Hall's data with their own fatigue data, Moore and Henwood showed a table illustrating the stress-concentration factors for the two types of screw threads (106). The stress-concentration factor was determined from the ratio of the endurance strength of a smooth test specimen to that of a specimen with the respective thread, Table 4.

From photoelastic studies of threaded connections, Solakian (96) found that relative stress-concentration effects for the Whitworth, the American Standard, and the Sellers square thread were, respectively, 1, 1.3, and 2.6.

Additional data illustrating the influence of thread contour were published by Cazaud (107), following work undertaken by the French Air Ministry.

Rotating-cantilever-beam tests were carried out on three types of specimens, threaded with (*a*) sharp 60-deg-angle thread, (*b*) rounded 60-deg-angle thread, (*c*) half-round thread (this last being a continuously rounded thread both at the root and at the crown, with no straight portion). The results are shown in Table 5.

TABLE 3 TESTS OF DIE-CUT WHITWORTH AND U. S. STANDARD THREADS

	Endurance strength, psi		
Thread	None	Whitworth	U.S. Standard
Medium-carbon steel	37000	21000	13000
S.A.E. 2320	73000	22000	19000

TABLE 4 STRESS-CONCENTRATION FACTORS FOR VARIOUS SCREW THREADS

		Stress-concentration factor	
Thread	Metal	Fatigue test	Photoelastic method
U. S. Standard	Medium-carbon steel	2.84	....
	S.A.E. 2320, heat-treated	3.85	5.62
Whitworth	Medium-carbon steel	1.76	....
	S.A.E. 2320, heat-treated	3.32	3.86

TABLE 5 RESULTS OF ROTATING-CANTILEVER-BEAM TESTS ON VARIOUS THREAD TYPES

	Reduction in fatigue strength, per cent			
	Annealed steel	Untempered Cr-Ni steel	Tempered at 200 F Cr-Ni steel	Tempered at 650 F Cr-Ni steel
No threads	0	0	0	0
Sharp angular threads	26	89	76	50
Rounded angular threads	22	76	63	43
Half-round threads	20	65	57	38

By rounding off the root of the thread in one of their investigations, changing from a 0.1 mm radius to a 0.2 mm radius, Thum and Staedel increased the fatigue strength 50 per cent (84).

EFFECT OF SURFACE-ROLLING

The beneficial effect of surface-rolling on fatigue strength has been known for some time. Föppl (30) increased the bending fatigue strength of steel rods as much as 20 per cent by means of

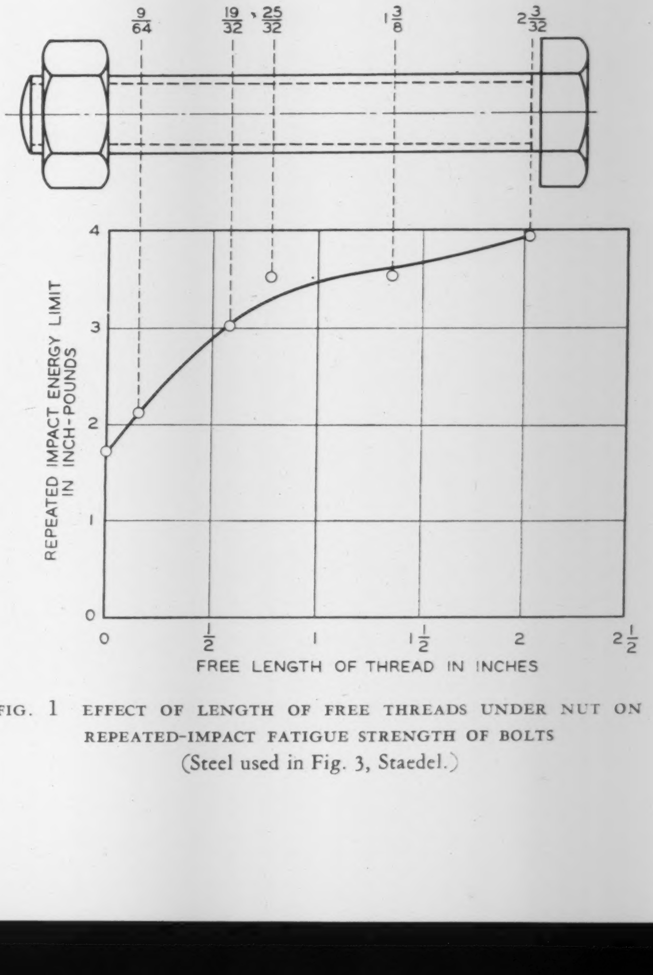


FIG. 1 EFFECT OF LENGTH OF FREE THREADS UNDER NUT ON REPEATED-IMPACT FATIGUE STRENGTH OF BOLTS

(Steel used in Fig. 3, Staedel.)

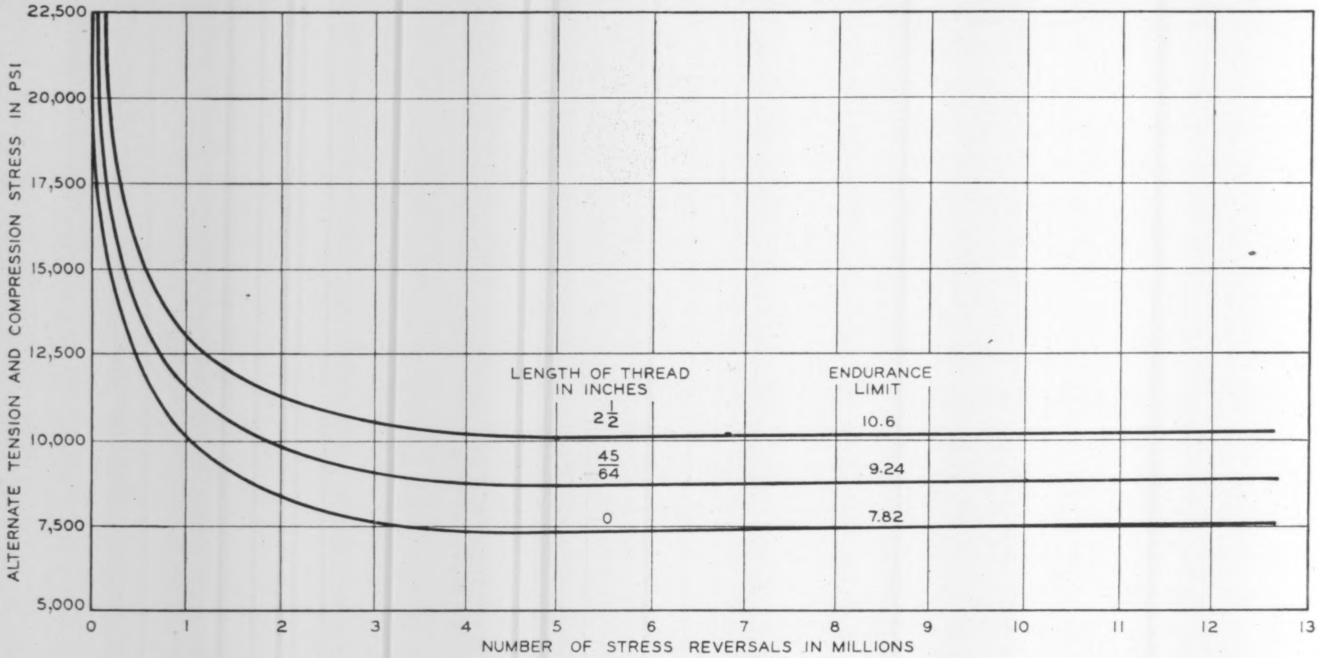
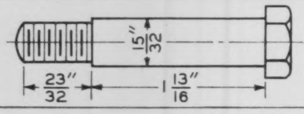
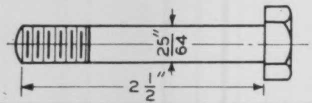
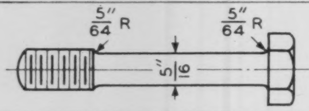
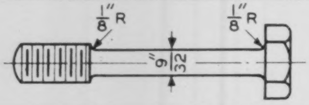
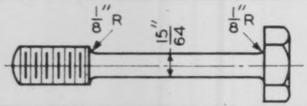


FIG. 2 EFFECT OF LENGTH OF FREE THREADS UNDER NUT, ACCORDING TO FIG. 1, ON ALTERNATE TENSION-COMPRESSION FATIGUE LIMIT OF BOLTS

(Bolt material with 61,000-psi ultimate strength and 41,300-psi yield strength, Staedel.)

BOLT DESIGN	BOLT BODY		BOLT BODY AREA IN PER CENT OF AREA AT ROOT OF THREAD	REPEATED IMPACT FATIGUE LIMIT					
	DIAMETER IN INCHES	AREA IN SQUARE INCHES		STEEL A		STEEL B		STEEL C	
				INCH-POUNDS	PER CENT	INCH-POUNDS	PER CENT	INCH-POUNDS	PER CENT
1 	$\frac{15}{32}$	0.175	230	1.73	100	1.73	100		
2 	$\frac{25}{64}$	0.122	160	2.60	150	2.26	130	~2.17	100
3 	$\frac{5}{16}$	0.076	100	4.34	250	2.78	160	~3.47	160
4 	$\frac{9}{32}$	0.060	78	5.21	300	2.95	170	5.21	240
5 	$\frac{15}{64}$	0.044	57	6.51	375	3.65	210		

	COMPOSITION IN PER CENT					ULTIMATE (PSI)	YIELD (PSI)	PER CENT ELONGATION	PER CENT REDUCTION IN AREA	BOLT * ULTIMATE
	C	Mn	P	S	Si					
STEEL A	0.15	0.65	0.095	0.186	0.04	78,200		12.8	56.0	93,900
STEEL B	0.25	0.75	0.019	0.024	0.25	96,400		12.8	54.0	118,900
STEEL C	0.33	0.70	0.039	0.027	0.18	85,300–99,600	>68,300	16-10		118,000

* STATIC TENSILE STRENGTH OF ACTUAL BOLT, DESIGN 2. HAVING $\frac{5}{32}$-INCH LENGTH OF FREE THREADS UNDER NUT

FIG. 3 EFFECT OF BODY DIAMETER OF BOLT AND BOLT STEEL ON REPEATED-IMPACT FATIGUE STRENGTH OF BOLTS, STAEDEL

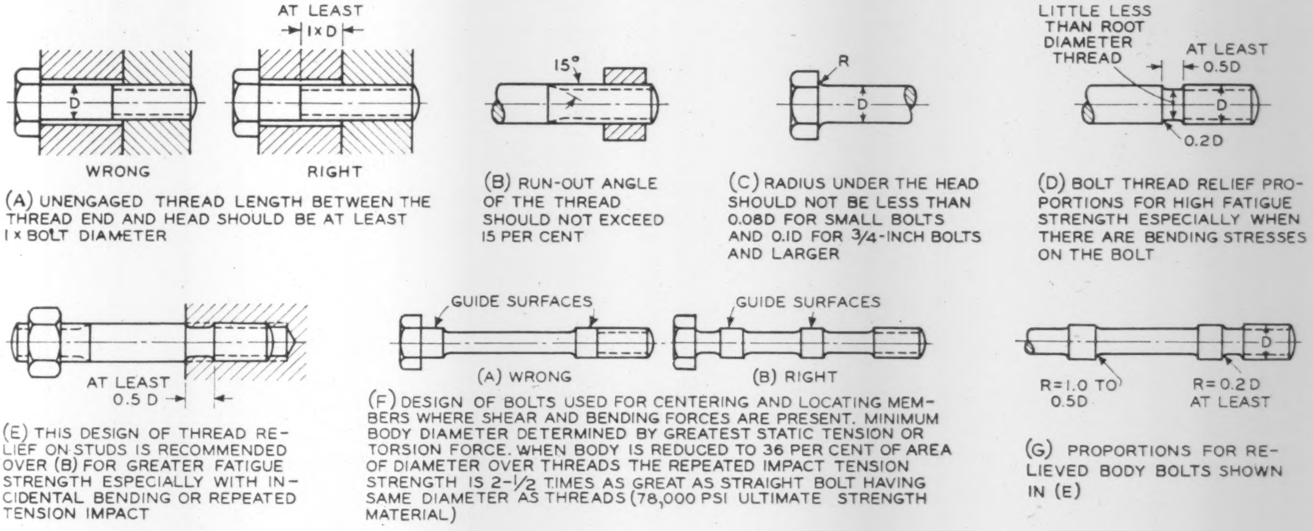
surface pressure. Shortly after this, Isemer (53) published some data showing an improvement of 20 per cent in the bending fatigue strength of screws by compression of the roots, although little improvement was obtained by pressure on the thread sides.

Other authors have shown data indicating increased fatigue strength of threaded parts by rolling (84, 93, 129), and Wedemyer obtained an improvement of 10 per cent by subsequent rolling even in the case of a rolled thread (131). For a cut thread, the endurance strength was increased 40 per cent by this means. The last author points out that the optimum pressure must be determined for each material. The roller should be very hard, accurate, and made to an angle approximately 5 deg less than the included angle of the thread.

The improvement following this surface rolling is probably due to the removal of surface imperfections and surface consolidation according to Föppl, and is not due to compensatory internal stresses (133). All material does not respond to rolling of the threads, so that this factor also must be determined for specific materials (62).

INFLUENCE OF TEMPERATURE ON ENDURANCE STRENGTH

The effect of temperature on the fatigue strength of a threaded part has not been widely studied. Bertram (155, 159) ran endurance tests on three steels and found that the beneficial effects of rolling the thread roots were retained up to a temperature in the neighborhood of 1000 F. However, the tests were run in a nonstandard manner so that the data are not readily applied. The indications are, however, that an increase in temperature to 500 deg above the ambient may result in a decrease in torsional fatigue strength of the threaded material of 15 to 25 per cent.



(A) UNENGAGED THREAD LENGTH BETWEEN THE THREAD END AND HEAD SHOULD BE AT LEAST 1 × BOLT DIAMETER

(B) RUN-OUT ANGLE OF THE THREAD SHOULD NOT EXCEED 15 PER CENT

(C) RADIUS UNDER THE HEAD SHOULD NOT BE LESS THAN 0.08D FOR SMALL BOLTS AND 0.1D FOR 3/4-INCH BOLTS AND LARGER

(D) BOLT THREAD RELIEF PROPORTIONS FOR HIGH FATIGUE STRENGTH ESPECIALLY WHEN THERE ARE BENDING STRESSES ON THE BOLT

(E) THIS DESIGN OF THREAD RELIEF ON STUDS IS RECOMMENDED OVER (B) FOR GREATER FATIGUE STRENGTH ESPECIALLY WITH INCIDENTAL BENDING OR REPEATED TENSION IMPACT

(F) DESIGN OF BOLTS USED FOR CENTERING AND LOCATING MEMBERS WHERE SHEAR AND BENDING FORCES ARE PRESENT. MINIMUM BODY DIAMETER DETERMINED BY GREATEST STATIC TENSION OR TORSION FORCE. WHEN BODY IS REDUCED TO 36 PER CENT OF AREA OF DIAMETER OVER THREADS THE REPEATED IMPACT TENSION STRENGTH IS 2-1/2 TIMES AS GREAT AS STRAIGHT BOLT HAVING SAME DIAMETER AS THREADS (78,000 PSI ULTIMATE STRENGTH MATERIAL)

(G) PROPORTIONS FOR RELIEVED BODY BOLTS SHOWN IN (E)

FIG. 4 RECOMMENDATIONS FOR BOLT DESIGN WHEN HIGH FATIGUE STRENGTH IS REQUIRED, STAEDEL

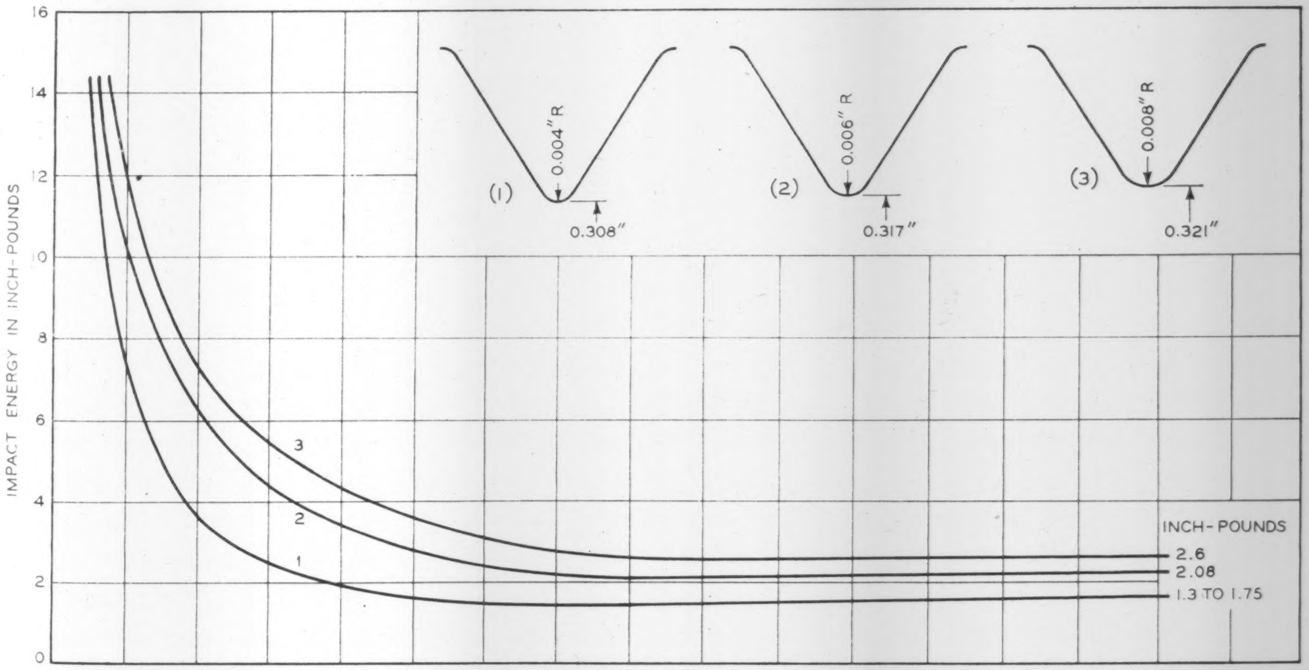


FIG. 5 EFFECT OF ROOT RADIUS OF THREAD ON REPEATED-IMPACT FATIGUE LIMIT OF BOLTS
(Steel *C* used in Fig. 3, Staedel.)

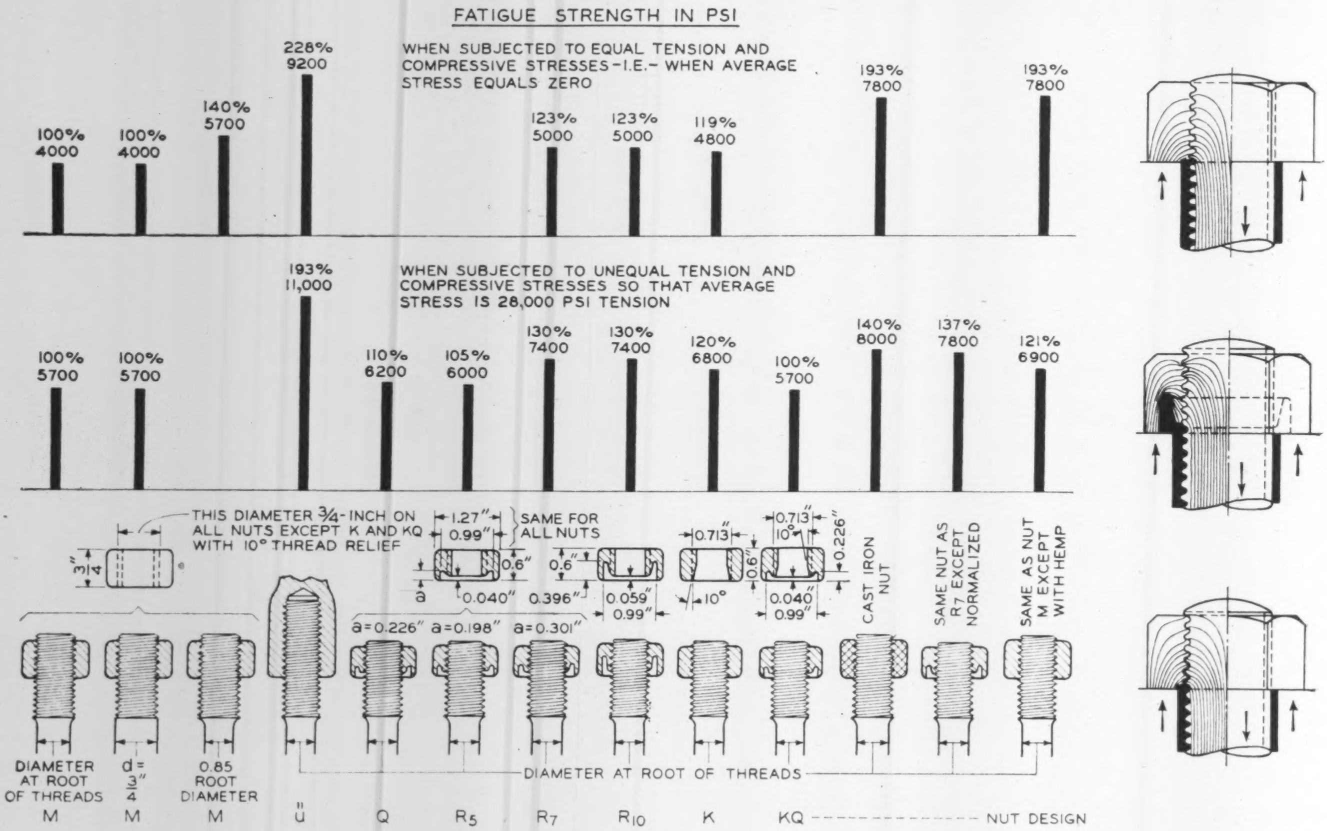


FIG. 6 FATIGUE STRENGTH OF VARIOUS THREADED JOINTS

(All nuts hot-pressed unless otherwise noted. Bolt iron composition 0.06 C, 0.51 Mn,0. 077 P, and 0.036 S; tensile strength 61,000 psi; yield point 41,000 psi; elongation 31 per cent, with 69 per cent reduction in area, Wiegand.)

IMPROVING FATIGUE STRENGTH OF THREADED MATERIALS

For securing optimum endurance strength of threaded parts, a number of recommendations have been made. While some of them involve major changes in methods of fabrication, others could be adopted with a minimum of effort. Figs. 1 to 5, taken from a paper by Horger and Buckwalter (156), illustrate several of these changes.

One suggestion concerns the length of the free thread between the head of a bolt and the nut. This should be at least equal to the diameter of the bolt (93, 112). In addition, the length of the threaded part should be at least one and one half times the diameter (84). Thum has shown that for highest strength, the free thread above the nut should be at least twice the thickness of the nut. For a bolt threaded for only the thickness of the nut, the endurance strength dropped to one third (105).

Staedel (93) indicated that the chamfer angle of the thread is important and should not be greater than 15 deg.

Considerable improvement in fatigue strength has been obtained by reducing the material in the shank above the threaded section. This can be done by reducing the diameter of the shank, or by means of a concentrically bored hole along the longitudinal axis as far down as the beginning of the threaded portion (84, 93, 162).

Static tensile properties of materials have often been improved by means of stress-relieving notches. This treatment has been extended to threaded parts subjected to repeated stressing. Improvement in endurance has been obtained with a rounded circumferential groove in the shank immediately above the threads (84, 93, 99).

Confirming what has been shown repeatedly in more general fatigue studies, there should be a generous fillet rather than a sharp angle between the head of a bolt and the shank (9, 84, 93).

Packing a material such as hemp in the thread groove will aid in maintaining a tight fit, and yet this material will deform enough to moderate maximum stresses set up at specific areas. By means of such packing, the endurance strength of $^3/_4$-in. screws was increased 21 per cent (92, 156).

The maintenance of a tight connection between the nut and bolt threads is important. This has been pointed out by several authors, but the optimum value for the initial tightening apparently differs with the material, and these values (91, 105) have not been determined as yet. The use of a lock nut helps to maintain the tight connection and by so doing minimizes the impacts suffered by the threads in a loose joint (14).

INFLUENCE OF THE NUT

The material of the nut as well as the design affect the fatigue strength of a screw joint. By using nut material with a lower modulus of elasticity than that of the bolt, the nut will conform more readily to any distortion of the bolt threads and maintain more uniform contact pressure (112, 140). This lower modulus and the fact that it is only slightly notch-sensitive may explain why cast-iron nuts on steel bolts have been superior in endurance to steel in some applications. Wiegand (140) shows several curves indicating the superiority of cast-iron and light (aluminum) alloy nuts on steel bolts, as compared with steel nuts in some tension-compression fatigue tests.

The fact that the first few threads in a screwed joint bear most of the load is borne out by actual failures in service, the fracture generally taking place in this region. Additional evidence is given by photoelastic studies which show high stress concentrations in the threads near the face of the nut (126, 156). By tapering the screw threads, the distribution of the load can be made more uniform, with a resulting increase in endurance (91, 95, 112). An improvement of 20 per cent was noted for some $^3/_4$-in. screws (92).

There are other methods of more equitably distributing the load. Thus, an annular notch, cut in the face of the nut, increased the fatigue strength up to 30 per cent in the case of some $^{3}/_{4}$-in. screws (92, 95, 112, 156). The depth of the notch is important and Wiegand (95) shows results obtained for several notch depths.

While the fatigue strength was improved both by the use of a tapered thread and also by means of the annular notch in the face of the nut, the simultaneous use of both did not result in further improvement. On the contrary a decrease in endurance was noted (95). Horger (126) illustrates several of the recommended changes and these are shown in Fig. 6.

Improvement in load concentration can also be obtained by reducing the friction between the threads and between the face of the nut and its support. Both rounding the base of the nut so that contact takes place over a circle instead of an annulus and making axial cuts into the wall of the nut from the outside aid in this respect (151).

While there has been some question as to the optimum height for the nut, Wiegand (95) concluded from his work that the minimum thickness of the nut should be 0.7d (where d = the bolt diameter). The value 0.8 d has also been suggested (57, 152).

CONCLUSION

As noted in the preceding review, there are numerous modifications of threaded parts which have been recommended in attempts to increase the endurance strength of screwed joints. For the purpose of summarizing these recommendations briefly, they may be grouped into three broad classifications, as follows:

The first concerns the choice and treatment of the material to be used as screw stock. Obviously, such choice must largely be determined by the over-all strength requirements. In general, material which is not notch-sensitive is desirable.

Then there are those changes affecting the physical dimensions and shape of the threaded part. Among these may be considered rounding of the thread contour, more equitable distribution of stress over the thread surface, and an increase in the length of the threaded surface.

Finally, are those recommendations which concern what may be considered post manufacturing treatment. These include maintenance of tight connections, rolling of the thread surface, and use only of those metallic coatings which do not exert a deleterious effect from the standpoint of fatigue.

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FINISHES *for* PLYWOOD *in the* AIRCRAFT INDUSTRY

By ROY B. ANDERSON

INDUSTRIAL RESEARCH DIVISION, WIPE-ON CORPORATION, NEW YORK, N. Y.

PLYWOOD of the resin-bonded type may be shaped or molded and subsequently retain its form under practically every condition of humidity and climate. It is therefore quite understandable why this new plywood is being applied to the manufacture of an ever-widening variety of products, among which, and of greatest importance, is aircraft. It is in the latter field that the problem of providing the proper type of protective coatings or finishes for the plywood is most vital.

As used in this paper the word "finishes" connotes direct coatings of the commonly called paint, varnish, or lacquer type, not those types referred to as fabric coating, impregnation, resin-treated paper, or textile. The plywood referred to is the type bonded with synthetic-resin glues.

REQUIREMENTS OF THE IDEAL FINISH

The ideal finish must meet the demands of the aircraft designer and engineer for protection, weight, smoothness, and service; the needs of the production department for easy and quick processing, and the requirements of simple and speedy refinishing in the field. The requirements of such an ideal finish might be listed in order of importance as follows:

1 To minimize the passage of moisture through the film.

2 To have long life and durability in resistance to weathering and hard usage.

3 To meet weight requirements.

4 To be satisfactory and quick in application during production.

5 To have necessary smoothness of film, depending upon type of service, whether combat, transport, or trainer.

6 To be easily and speedily maintained and refinished in the field.

The relative importance of the third, fourth, and fifth requirements depends upon the type of airplane and production factors.

No consideration will be given at this time to the cost of the finish itself, because the initial material cost is so small in comparison with the processing, service, or possible weight-saving value.

Material costing $10 per unit might be more economical to the processing engineer than a unit costing only $1, because of time and space saved by a more rapidly drying finish. The cheaper finishing material might even cost a great deal more in service because of its shorter life and earlier need of refinishing. Again, the more costly material might prove decidedly more economical in view of possible weight saving, particularly in cargo planes, thus providing for a heavier pay load. Should the purchasing department give this kind of consideration to these cost factors, rather than unit cost per gallon, the resulting savings to the airplane manufacturer might be considerable.

MOISTURE RESISTANCE A PRIME REQUISITE

One of our most widely recognized experts on wood, H. D. Tiemann, reports[1] that wood has "one great inherent fault for almost every purpose for which it is used—it is hygroscopic. That means it will shrink and swell."

This is one of the reasons why moisture resistance is one of the first requirements for the ideal finish. Other recognized reasons include the following:

In Relation to the Weathering of Wood. The most important requirement of a protective coating, i.e., paint, varnish, lacquer, enamel, or primer, is resistance to moisture penetration. This is true whether we are protecting wood or metal.

In protecting wood, moisture resistance of the film is of fundamental importance. The Forest Products Laboratory describes the warping, weathering, and checking of wood (with consequent loss in strength), as due to swelling under humid or wet conditions because of moisture absorption and the subsequent shrinkage under dry conditions. According to Dr. F. L. Browne of the Laboratory, this constant weaving of the wood structure is the disintegrating cause of wood failure.[2] Dr. Browne goes on to summarize: "This moisture-retarding effectiveness of paint coatings is the physical property upon which their protective value for wood depends." Tests for measuring this moisture absorption are described. In a later article,[3] he again maintains that the "protection afforded wood by paint coatings can be measured in terms of effectiveness against moisture movement." The Forest Products Laboratory further points out the necessity of highest moisture resistance in the priming or first coat in protecting not only the wood but the subsequent coats of paint as well.

The work of the Forest Products Laboratory is also confirmed by the several papers of Edwards and Wray of the Aluminum Company of America, who present data indicating that "paint coatings continue to protect wood adequately against weathering only so long as they maintain a reasonable degree of moisture-excluding efficiency." They also argue that "the process of wood weathering is principally due to the disintegrating stresses set up in the wood as a result of the fluctuating moisture content of those portions exposed directly to the weather. Moisture-proofing-efficiency and wood protection go hand in hand."[4]

Change in Weight of Wood With Moisture Absorption. Aside from the weathering effect due to moisture intake is the very important question of the increase in weight of the wood under high-humidity conditions, if the surface is not properly protected.

In a report[5] of the Forest Products Laboratory, the moisture content of wood is given for various temperatures and humidities, as for example:

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[1] "Wood Technology," by H. D. Tiemann, Pitman Publishing Corporation, New York, N. Y., 1942.

Contributed by the Wood Industries and Aviation Divisions and presented at the Spring Meeting, Davenport, Iowa, April 26–28, 1943, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

[2] "A Principle for Testing the Durability of Paints and Protective Coatings for Wood," by F. L. Browne, *Industrial and Engineering Chemistry*, vol. 19, 1927, pp. 982–985.

[3] "Paints as Protective Coatings for Wood," by F. L. Browne, *Industrial and Engineering Chemistry*, vol. 28, 1936, p. 799.

[4] (*a*) "Protecting Wood With Aluminum Paint," by J. D. Edwards and R. I. Wray, *Industrial and Engineering Chemistry*, vol. 19, 1927, pp. 975–977.

(*b*) "Permeability of Paint Films to Moisture," by R. I. Wray and A. R. Van Vorst, *Industrial and Engineering Chemistry*, vol. 25, 1933, pp. 842–846.

[5] "Change in Weight of Wood With Moisture Absorption," Forest Products Laboratory, Technical Report No. D-5.

Relative humidity, per cent	Moisture content of wood at 70 F per cent
20	4.5
40	7.7
60	11.2
80	17.0
100	32.0

Thus, in wet weather, if the plywood has not an adequate coating, the "dead weight" of the wood structure may increase more than 25 per cent. This is worthy of serious consideration.

Loss in Wood Strength With Increased Moisture Content. Engineers have long been interested in the strength-weight ratio of wood but have realized that one of its disadvantages is its affinity for moisture. George B. Parsons, chief of stress and structure research of the Duramold Aircraft Company, refers to this in a recent article.[6] Mr. Parsons gives data on the great changes caused by moisture in plywood on such properties as modulus of elasticity, modulus of rupture and tension, and compression parallel to the grain. He refers to the efficiency of a 7 to 9 per cent moisture content in the wood, although 12 per cent is more or less the standard adopted, and mentions the use of a protective coating on the wood to keep the moisture content low. In a series of curves, he shows the quantitative data for loss of strength properties of six woods as the moisture content increases from a normal of 12 per cent to values of 24 per cent. An example is given in Table 1.

TABLE 1 LOSS OF STRENGTH PROPERTIES FOR BIRCH, WITH INCREASING MOISTURE

(Standard value taken at 12 per cent moisture content)

	At 18 per cent moisture content (approx)	At 24 per cent moisture content (approx)
Modulus of elasticity..	0.9 Of original value	0.8 Of original value
Modulus of rupture and tension............	0.76 Of original value	0.6 Of original value
Compression parallel to grain...........	0.7 Of original value	0.5 Of original value

Similar large strength losses are shown with increased moisture content for Sitka spruce, red gum, basswood, yellow poplar, and African mahogany. The importance of adequate surface coating is emphasized in the foregoing values. For example, the compression value parallel to the grain may be reduced one half by increasing the moisture content to 24 per cent. By referring to the Forest Products Laboratory moisture-content example previously tabulated we note that 24 per cent moisture gain may be easily obtained with inadequate surface protection since this value may run to 32 per cent at 100 per cent relative humidity.

Grain Raising and Speed. One of the important advantages accomplished by plywood-aircraft construction is the smooth streamlined surface free from rivets and seams, thus achieving nearly ideal aerodynamic qualities. If a high degree of moisture resistance is not present in the coating, then this streamlining and its resulting speed are sacrificed due to the grain raising of the surface which occurs with moisture absorption.

EFFECTIVENESS OF MOISTURE-EXCLUDING COATINGS

It is known that no protective coating or finish will prevent the complete passage of moisture through the film. Protected wood will reach moisture equilibrium with the surrounding atmosphere if subject to this atmosphere for a sufficient time.

The moisture-excluding effectiveness of the coating determines the length of time before the wood reaches equilibrium. Thus the more effective the coating is to moisture resistance, the slower is the cycle of moisture passing into or from the wood, and there is less danger to weathering of the wood, weight pick-up, loss in strength, or grain raising.

The majority of the pioneers in plywood aircraft construction, realizing that moisture-excluding effectiveness was the primary requirement for a coating, specified and used coatings possessing this quality to the highest possible degree obtainable, without, of course, sacrificing any of the other needed qualities to an inadequate extent. These coatings, used by them have proved, over a period of years, their ability to meet every requirement of plywood aircraft usage. However, recent government specifications now permit the use of finishes and coatings of a much lower moisture-excluding effectiveness.

As it takes considerable time to prove conclusively the value of a plywood-aircraft finish to provide adequate protection under the various flying and climatic conditions to which an airplane is exposed, it is hard to see how the lowered moisture-excluding effectiveness permitted can be accepted as adequate because there has not been a sufficient time to prove the permitted degree.

If these coatings should fail to provide sufficient protection from moisture absorption or loss, the result would be lowered operating efficiency of the aircraft, danger to personnel, and the discontinuance of the use of plywood as an aircraft material.

Is it not sound, therefore, to take the stand that, until conclusive evidence is established that a lower degree of moisture-excluding effectiveness is adequate, the more moisture-resisting types of proved and time-tested coatings should only be accepted as satisfactory for plywood aircraft use? We believe this should be given very careful and serious consideration.

Among the many performance requirements of moisture-excluding coatings, these are essential in measuring their life:

Elasticity to Resist Changes in Temperature. Temperatures may change rapidly from plus 150 F to minus 70 F, depending upon location and flying altitudes, so naturally the protective coating must be sufficiently flexible and plastic to expand and contract with the wood as the temperature changes, as the moisture content in the wood fluctuates, and still withstand flexing and bending under all service conditions. Unfortunately, the requirements of elasticity make it difficult in formulation because these requirements run counter to the requirements for speed in drying and hardness to resist abrasion. However, the plywood planes of the last 7 years have shown that these difficult requirements may be met satisfactorily so that adequate moisture resistance and other use demands may be obtained with fast finishing schedules.

Toughness Against Impact. The finish must be hard to resist the impact of hail and sand in flying, stone bruises upon landing, as well as foot wear and rough use of tools or gasoline hose in maintenance and repair work.

Resistance to Fluids. There must be no damaging effect to the finish from spilled gasoline, deicing, or leaking brake fluids.

Adhesion Over Glue Joints. The finish should not break away from butt or scarf joints, or over surface areas where there might be an excess of glue. Neither should the finish fail over fabric or paper used either over end grain or over some joints.

WEIGHT CONSIDERATIONS

The weight factor is of primary importance, particularly in the design of cargo planes and gliders. Because the moisture-excluding effectiveness is sacrificed as the weight or thickness of finish is reduced, careful consideration must be given to balancing the weight factor against moisture resistance. The type, use, or life of the plane is a controlling factor. A cargo plane demands a finish in which consideration of weight rather than moisture resistance is the greater. An amphibian glider, on the other hand, must have both extreme moisture resistance and light weight in its finish or protective coating. In view of the fact that this relation between weight of finish and its moisture-exluding effectiveness is so important, it is recommended that those finishes of highest moisture resistance be used because then weight or thickness of film can be kept to a minimum without undue sacrifice in moisture resistance.

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[6] "Strength Characteristics of Plastic Bonded Plywood," by G. B. Parsons, *Aero Digest*, vol. 41, July, 1942, pp. 160, 162, 165, 273–274.

PROCESSING REQUIRES SATISFACTORY AND QUICK APPLICATION

In formulating a finish to meet the performance specifications for moisture resistance, durability, and weight, consideration must also be given to the method of application to meet the finishing requirements in the airplane factory. The following must be considered:

Application. The brush, spray, or dip method is normally used either by itself or in combination with the one or both of the other means. The brush and spray methods are ordinarily used, and fortunately, almost any type or formulation of finish will meet their requirements. When application by dipping is to be used, consideration must be given to flow so that the finish will drain easily, and to stability so that the material in the dipping tank will not become heavy, thus interfering with flow, nor become solid from oxidation or polymerization.

Quick Drying. From the processing engineer's viewpoint, the faster the drying time, the better. In view of the fact, however, that flexibility might be sacrificed for extremely fast drying, it is necessary to weigh drying characteristics against performance in formulating the ideal finish. It is accepted practice to use forced-drying ovens for those finishes which might dry too slowly at room temperature.

Sanding. Here again, the time and labor of sanding must be weighed against smoothness and appearance in formulating the ideal plywood-airplane finish.

Masking Glue Joints. Masking glue joints is necessary when the finish is applied to interior surfaces before the joint is glued, because glues now available do not adhere satisfactorily to present-day sealer finishes. Consideration is being given to the ideal type of sealer over which glues will stick. Such a sealer will overcome the troublesome and costly masking of glue joints.

MAINTENANCE AND REFINISHING IN THE FIELD

This consideration in the formulation of the ideal finish is similar to the conditions described under moisture resistance and processing requirements in the airplane factory. The finish must withstand washing and scrubbing, and no complicated apparatus should be necessary for easy refinishing.

SMOOTHNESS DEPENDS UPON USE AND APPEARANCE OF PLANE

The smoothness of the ideal finish requires consideration depending upon the type of wood, whether open or close grain; the method of construction because of nail or staple holes, dents, or blemishes; the consideration of speed; and finally appearance. Although smoothness has been a prime factor during recent years, less consideration is being given to smoothness now because of the needed speed in production and the possible weight saving. Smoothness, however, is still of great importance for combat planes because of the resulting increase in speed. This factor too must, therefore, be weighed carefully in formulating the ideal finish.

FINISH CONSISTS OF DIFFERENT PRODUCTS TO BUILD THE SYSTEM

To build such an ideal finish to meet the performance and finishing requirements as described previously, it is necessary to use several products for the exterior coating, although one product will generally suffice for the interior surface not exposed to view, and two for the interior surface exposed to view.

The exterior finish consists generally of three products:

1 A sealer for close-grain woods or a sealer-filler for open-grain woods. The function of this product is to seal the wood against moisture penetration and to provide a surface for the exterior coats. The composition and physical properties of the sealer must be based upon experience to provide not only penetration and moisture resistance but compatibility and adhesion for the subsequent coats.

2 A surfacer coat to provide added moisture resistance and sufficient build-up for smoothness and durability.

3 A final coating to provide color, appearance, and durability to resist weathering and hard usage.

The finish for interior surfaces not exposed to view generally consists of only one product, namely, a sealer, whose primary purpose is to protect the wood from moisture. For these interior surfaces exposed to view, it is the usual practice to apply a color coat over the sealer for appearance.

Besides the products which make up the exterior- and interior-finishing systems, it is necessary to use specially prepared putty for nail holes, dents, and blemishes; and also properly formulated products for end grain not covered by tape.

THE IDEAL FINISH MUST BE FORMULATED PROPERLY

Having set up a yardstick to measure the requirements of a plywood-aircraft finish, and knowing the products which make up such a finishing system, it is now the work of the scientist to formulate the ideal finish.

Eight years ago the author's company started its research toward the development of plywood-aircraft finishes. In collaboration with leading plywood manufacturers, aircraft manufacturers interested in plywood construction, and synthetic-resin manufacturers, hundreds of formulas were developed and over 5000 panels were finished and the coatings tested for weathering, flexing, extremes of temperature, drying time, application methods, etc. Over 12,000 individual tests alone were run on moisture resistance. From these tests, systems were established and applied to plywood airplanes. When these planes had been flown for a considerable number of hours under the most severe conditions to which aircraft of this type would be exposed, the surface conditions of the coatings were checked and analyzed, and necessary formula changes were made and again checked. This "proof-of-use" study extended over a period of 6 years.

THREE DIFFERENT TYPES OF COATINGS TESTED

Cellulose Type; Lacquer and Dope. This type was promising from the viewpoint of easy and extremely quick application, both during processing at the factory and refinishing in the field, but from the viewpoint of performance, the results were rather unsatisfactory because of cracking from insufficient flexibility and because of poor moisture resistance. From knowledge that we have been able to obtain at this time, this type of coating appears to be unsatisfactory for use on plywood-aircraft surfaces.

Alkyd Type. The alkyd plywood-aircraft finishes have met with moderate success in the laboratory but they may not as yet have had sufficient length of service in the field to prove that they will meet satisfactory performance requirements. It appears that this type of coating has satisfactory durability and flexibility, but, from the viewpoint of poor moisture resistance and slow drying, the final rating cannot be satisfactorily determined until the time when performance records in the field and factory are thoroughly established. For those plywood airplanes, where streamlining is such an important factor, consideration must also be given to the danger of "grain raising," because of the poorer moisture resistance of this type of finish.

Another consideration which must be given to the use of the alkyd type of finish is in connection with dipping. This requires a large dip tank filled with the finishing material which has a tendency to thicken.

Many plywood-aircraft surfaces have been finished with the alkyd type of direct-finishing system during the last several months, and the performance records of these surfaces should be studied carefully in the next 6 or 12 months so that this type of finish may be evaluated and adjustments made in formulation if necessary.

Phenolic Type. This type of plywood-aircraft finish has proved its ability to meet the requirements better than any other type up to this time. Regular field inspection reports, covering the condition of phenolic finishes on many thousands of plywood-aircraft surfaces, indicate very satisfactory performance.

However, a type of failure has been noted, over weak structural areas, which causes the outer surface of the plywood skin to crack, in which case the crack extends through the finish coating. Changes in design to eliminate the cracking of the plywood skin appear to overcome the cracking of the surface coating. Since it seems quite impossible to prevent a crack from appearing in a surface coating, if the crack originates in the plywood itself, may this not be considered as an advantage for the paint-coating type over the fabric-covered type of plywood, because in the fabric type, the plywood crack may not be noticed and serious plywood failure might result?

The phenolic type has remarkable resistance to the passage of moisture through the film, and, consequently, proves of great advantage where weight of finish is a factor, because the phenolic finish can be so much lighter in weight and thickness of film and still have satisfactory moisture resistance. One examination was made on this type of finish that had given actual field service of 1700 flying hours on a plywood trainer. The moisture-excluding effectiveness of this aged film was measured against a new film and practically no loss in effectiveness had resulted after so many hours in the air.

For more than a decade, the high moisture resistances of the 100 per cent phenolic coatings have been generally recognized and accepted by the coatings industry and by specification engineers. As a representative example of such coatings, refer to spar-varnish water-resisting specifications, such as, AN-TT-V118, the Naval Aircraft Varnish Specification V10, Navy Department spar varnish and vehicle No. 80, and the phenolic-resin specification AN-TT-R-27. The strategic coatings specified by the U. S. Engineers are based on similar 100 per cent phenolic resins.

Proof of the superior moisture resistance of the phenolic type of finish, as compared to other types, is found in reports of many recognized authorities.[7]

The phenolic type of finish meets processing requirements for application in the factory by the brush, spray, or dip methods, as well as refinishing in the field. The drying of this type of finish appears satisfactory but is somewhat slower than the cellulose type. Satisfactory drying, however, can be accomplished through the use of drying ovens.

OTHER CONSIDERATIONS IN THE IDEAL FINISHING SCHEDULE

Several other factors must be taken into consideration when formulating a finish for plywood-aircraft surfaces:

Available Supply of Raw Materials. As the supply situation becomes critical with some raw materials, it may be necessary to reformulate from such sources as might be available. This is a serious consideration at this time due, for example, to the expanding war use of phenolic resins and the limited supply until new manufacturing capacity can be brought into use. It is reported that new units will be in production in the near future. If it becomes necessary to curtail the use of these phenolic resins, it would appear to be unwise to exercise such restriction in the plywood-aircraft industry, thus forcing the use of finishes of other types which may not prove entirely satisfactory because of unestablished performance records. Should restriction of the phenolic or any other type of coating be necessary, it would appear that the only satisfactory solution might be to limit their use to the most essential applications rather than to eliminate them entirely. In this category are combat planes, amphibian gliders, and cargo seaplanes, where moisture resistance is of vital importance.

Government Specifications. Several of the government specifications for plywood-aircraft finishes must be taken into consideration when formulating.

Type of Service. Consideration must also be given to the requirements of the finish, depending upon the type of service to which the plywood will be exposed, as noted in Table 2.

TABLE 2 USES FOR PLYWOOD-AIRCRAFT COATINGS

Aircraft

Trainers

Gliders:
  Land-based
  Amphibian

Combat planes

Cargo planes:
  Land-based
  Water-based

Helicopter

Autogiro

Observation

Miscellaneous types

Parts

Wings
Wing tips
Fuselage
Bomb-bay doors
Stabilizers
Fins
Ailerons
Monocoque
Map cases
Flooring
Seats
Flaps
Nacelles
Elevator
Panels
Rudder
Tail cones

Factors to consider when evaluating a coating in relation to performance, use of plane, and production requirements

Moisture resistance in relation to:
  Weathering of wood
  Weight pick up
  Loss in wood strength
  Grain raising and speed

Durability to resist:
  Weathering
  Temperature changes
  Toughness
  Gasoline and fluids

Film weight

Application:
  Method (spray, brush, or dip)
  Speed of drying
  Masking glue joints
  Sanding time

Smoothness:
  Speed of plane
  Appearance

Refinishing in field:
  Speed of drying
  Ease of application

METHODS OF APPLICATION

There are several common methods of applying aircraft finishes, as follows:

Spray. This method of application, which is the one generally used, has proved very satisfactory because of the simplicity and speed in operation, and because all finishing shops are equipped with spray booths, gun apparatus, and necessary air pressure. The manufacturers of spray equipment are prepared to supply technical information and service. When forced- or oven-drying is used in conjunction with spraying, it is necessary to take precautions against pinheads and blisters which might form over open-grain wood. This usually occurs in the case of first-coat work and is caused by vapor, trapped in the valleys of the wood, expanding upon being heated. This condition can be overcome by allowing the first coat to dry hard. The author has inspected many airplanes in the field and from several thousands of performance records during the last 3 years has yet to notice any trouble of this kind in service.

Brush. This method of application is slow and more laborious than spray application but is satisfactory if the time and labor factors can be satisfied. There has been some discussion concerning the need of brush application for first-coat work rather than spray. The reason offered is that the brush forces the release of any trapped air, and thus overcomes the danger from pinheads or blisters. This advantage of brush application is recognized for use over fabric where the brush forces the coatings into the threads of the fabric. On wood, however, there is considerable question regarding the advantage of brush over spray application because of the rigidity of the wood and the difficulty of the brush hairs entering wood cavities and thus forcing trapped air to escape. Performance records on thousands of plywood-aircraft surfaces prove little or no advantage in the use of brush over spray application.

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[7] (*a*) "Effectiveness of Moisture Excluding Coating on Wood," by G. M. Hunt, Forest Products Laboratory, U. S. Department of Agriculture, Circular No. 128, Oct., 1930.

(*b*) "Kauri Reduction Versus Durability of Newer Types of Varnishes," New York Paint and Varnish Production Club, Scientific Section, Circular 423, 1932.

(*c*) "Exposure Tests of Pigments in 100 Per Cent Phenolic Versus Alkyds and Other Esters," Philadelphia Paint and Varnish Production Club, *Official Digest*, April, 1939.

(*d*) "Quantitative Permeability Measurements (100 Per Cent Phenolic Versus Alkyds and Other Types)," New York Paint and Varnish Production Club, Scientific Section, Circular 546, Nov., 1937.

(*e*) For further proof showing the advantage of the phenolic type of plywood-aircraft finish, reference might be made to several recent government publications that are available to the plywood-aircraft industry.

Dip. The dip method offers the most rapid and thorough means of application, and it is proving quite satisfactory for applying the sealer coats to the interior parts of wings, stabilizers, fins, rudders, and other small parts. The normal operation is to dip the object to be sealed into a tank containing the sealer, remove the object and allow it to drain and dry. The operation is repeated until sufficient sealer has been applied. During these operations, it is generally necessary to wipe the excess sealer from exterior surfaces by a cloth wet with solvent.

The application of sealer to interior surfaces of completely assembled parts by dipping overcomes the troublesome problem of masking glue joints on skins to be assembled after sealing.

Care must be exercised in design of the object to be dipped so that no trapped air in pockets will prevent the sealer from reaching all surfaces, and so that the sealer will drain completely, thus leaving none trapped to increase the weight.

In the dipping operations, consideration must be given to the size and design of the dip tank, and to the large quantity of sealer which must be tied up.

Another important factor is the stability of the sealer in the dip tank. Not all sealers are stable, and some become heavy, thick, and sometimes solid from evaporation, oxidation, and polymerization. Retarding agents are sometimes added at the request of the supplier of the sealer to overcome this condition, and as a result the sealer might take many hours longer to dry, thus slowing up production.

Wipe. This method is used mainly for wood fillers as recommended for open-grain wood. The material is generally applied by rags, dipped into the wood filler, and then wiped into the grain. After the solvents have evaporated and before hard drying, the filler is wiped off with rags, rubbing across the grain.

This is a very important operation because the better the grain is filled, the smoother will the surface be, and considerable savings can be effected in weight, film thickness, and labor, to produce a required degree of smoothness.

Some applications of the phenolic type of woodfiller have proved more effective against moisture penetration than applications of sealers. This sealer-filler type is of particular advantage for plywood aircraft surfaces of either the open- or close-grain type when exposed to sea water and when the resistance of moisture is such a factor.

Forced Drying. Several types of forced-drying systems have been tried by those aircraft manufacturers who require the speediest production possible because of their limited floor area and output requirements.

The use of an infrared heat source as the basis of one of these systems proved unsuccessful because of the danger from localized blistering. Although this method proves satisfactory on metal surfaces, it seems rather unsatisfactory in actual production on wood. This trouble from blistering might possibly be overcome if it were feasible to oscillate either the source of heat or the object being dried, so that the heat would not be concentrated in too small an area.

The use of rooms or ovens in which the temperature and humidity of the air are controlled has proved very satisfactory in regular production. The usual temperature of air is 130 F, with a relative humidity of 30 per cent. Under these conditions, it is normal practice to have a drying time of $4^{1}/_{2}$ to 5 hours for a finishing schedule, which under normal room temperature would require about 23 hours. For a finishing schedule, requiring 4 or 5 hours at normal room temperature, there might be a saving of approximately 50 per cent in drying time by using ovens or rooms, and the installation cost is moderate.

PRECAUTIONS TO OBSERVE IN THE FINISHING OPERATION

Glue Joints and Squeeze Outs. Excess glue should be prevented from collecting on the exterior surface of the plywood since at best the resin glues present poor surfaces for coating. This glue surface should be sanded with a coarse grade of sandpaper to provide a rough surface and tooth for proper adhesion of surface coats. It is an old habit in some woodworking shops to sand these areas very smooth, and this is bad practice in the aircraft industry because of the danger of poor adhesion of surface coats.

End Grain. Since exposed edges absorb moisture easily, it is advisable to protect them carefully. It is general practice to use tape over the end grain of inspection and oleo strut holes, gas-tank openings, and other exposed edges. The pinking tape is applied with dope and then finished the same as plywood. Some companies protect these edges with wood filler and several coats of an aluminum finish. Both methods are satisfactory if no opening is left in this end grain where moisture might penetrate. In the case of drain holes and other small openings difficult to treat as just recommended, it is general practice to use a heavy viscous type of sealer by brush or swab method.

Nail Holes, Dents, and Blemishes. These should be filled with a putty that is not too brittle, otherwise there might be a tendency to crack under some temperature changes or flexing.

Seams. Poorly jointed seams with wide glue lines or improperly bonded edges might cause cracking of top coats over these joints. Seams liable to develop cracking are hard to locate with assurance, but wide glue lines or veneer edges showing any tendency to lift should be regarded with suspicion.

Proper Working Conditions. Finishing rooms should be clean and the air well filtered in order to insure smooth clean work. Temperature control at about 76 F and a relative humidity of about 50 per cent are recommended. In some cases, however, even when the relative humidity might vary from 40 to 80 per cent with a constant temperature of about 70 F, it has been observed that the drying time is not sacrificed as humidity increases. Although this is contrary to old painting practice, it must be noted that the phenolic type of products was used, and good drying resulted.

Different Types and Brands of Coatings. These have sometimes been used in one finishing system, and this might prove very bad practice. Each product which enters into a finishing system should be carefully formulated for its specific purpose and to work satisfactorily with the coating in contact with it. A finish coat of the alkyd type might prove unsatisfactory over a lacquer system. A finishing system which employs an accepted phenolic type of sealer and a surfacer of the alkyd type might prove less durable than if a phenolic surfacer were used. The best type of finishing system generally consists of individual products which are known to be compatible with one another.

CONCLUSION

Many different groups have important interests in the behavior and ultimate service of plywood. Among the raw-material groups are the lumber and plywood industry, the manufacturer of synthetic-resin glues, and the producer of synthetic-resin coatings for the finished product. Vitally concerned also are fabricators, the prime contractors, and the subcontractors for aircraft and parts. Diffused through all these groups is the direct interest of the mechanical engineers, especially those in the A.S.M.E. Wood Industries Division. All of these groups sponsoring plywood must feel some technical responsibility for the protection afforded such plywood in service.

They must be watchful, therefore, that the carefully built-up experience of years of patient engineering is not ruthlessly discarded by hastily drawn specifications which disregard the prime requirements of such finishes. Such specifications, which are not based on engineering experience, may place in jeopardy not only the future expansion of plywood but the much more important consideration, our flying personnel. If the engineer is responsible for the performance, he must also be responsible for the specifications involved.

DIRECT-FIRED AIR HEATERS

Designed for Dehydration and Chemical Processes

By R. M. Rush[1] and B. B. Reilly[2]

DIRECT-FIRED self-contained air heaters, compact enough to fit into the operating floor of a modern industrial building, and capable of continuous operation over long periods without injury from the high temperatures developed by modern efficient combustion equipment, have been a matter of gradual development over the past 10 years. Since the war started, the use of these heaters has become an accepted method of heating aircraft plants, hangars, tank arsenals, and other buildings with large open spaces. They have been adopted chiefly because of the very great saving of steel and of man-hours of skilled labor, as compared with steam-heating plants of the same capacity.[3] Additional advantages have developed after their installation, such as saving of fuel as a result of high efficiency of heat abstraction and negligible radiation losses; speed of installation; availability for quick shipment; flexibility of the installation as regards later plant extensions; and the fact that skilled labor is not required for their operation. Such space heaters are available for oil, gas, or coal as fuel; and heaters designed for coal can easily be converted to oil or gas if changing conditions make those fuels available after the war. These heaters were previously described by one of the authors.[3]

These space heaters normally supply air at temperatures seldom exceeding 140 F, but today there is a growing demand for apparatus to furnish heated air at temperatures up to 350 F, for dehydration and chemical processes. It is with such heaters that the present paper deals.

HEATING REQUIREMENTS FOR DEHYDRATING PROCESSES

Hundreds of plants for drying vegetables, fruits, eggs, milk, meat, and hemp are to be built. Many chemical solutions are economically dried by spraying them into chambers through which large volumes of heated air are passed. In many cases the temperatures required are from 150 to 300 F, and high-pressure steam coils can be used. When higher temperatures are required, the heating of the air is sometimes effected in two stages; in the first stage, the air temperature is raised to 300 F with steam coils, and in the second stage to 450 F or higher by burning gas directly in the air stream and mixing the products of combustion with the heated air, Fig. 1. This method has been used where the available fuel is artificial gas, a rather expensive fuel. Where the less expensive natural gas is available, the simplest and cheapest method consists in the use of a single-stage duct-type heater, such as shown in Fig. 2.

Temperatures up to 1000 F can be obtained with this type of heater, and the control of temperature is accurate and dependble. These heaters also have been used successfully in installations where ventilation must be combined with heating and where large quantities of make-up air must be tempered. As will be evident from Fig. 2, the air to be heated is drawn over a gridwork of line burners, the latter being fed with the combustible mixture from Venturi mixers to which air is supplied from a pressure fan, while the gas is drawn in at low pressure. The fan is unnecessary if gas pressure is high enough. The line burners have flame-retaining tips which prevent the blowing out of the flame.

Oil-fired heaters, in which the products of combustion mix with the air are also available and in use where the danger of contamination of the product being dried is not a factor. In such a heater, combustion must approach perfection. One design which is in use is shown in Fig. 3. In this heater, oil is fired tangentially inside a refractory-lined cylinder or tunnel, giving a rotoflame effect. The refractory's becoming incandescent, not only causes positive and rapid ignition of the oil, but catalytically speeds up and completes the combustion. Only when starting up the apparatus, while the refractory is cold, are smoke or oil fumes encountered. The louvers are so arranged as to impart to the cold air entering through them a whirling

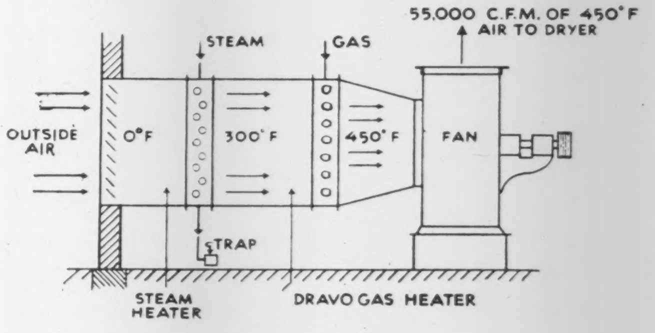
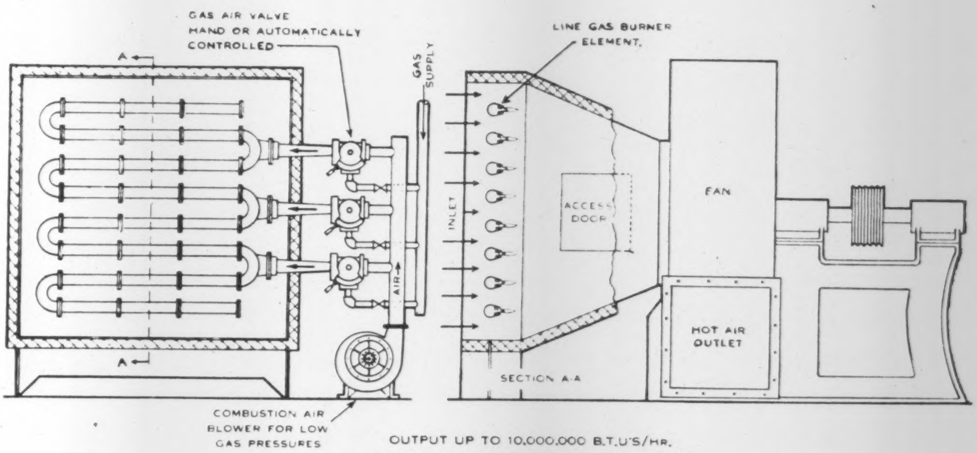


FIG. 1 DUCT-TYPE HEATER, GAS-FIRED, PRECEDED BY STEAM HEATER



OUTPUT UP TO 10,000,000 B.T.U'S/HR.
OUTLET TEMPERATURES UP TO 1,000° F.

FIG. 2 DUCT-TYPE HEATER, GAS-FIRED

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[1] Manager, Industrial Department, Dravo Corporation, Pittsburgh, Pa. Mem. A.S.M.E.

[2] Research Engineer, Heater Section, Dravo Corporation, Pittsburgh, Pa.

[3] "Development and Performance of a Coal-Fired Unit Heater," by R. M. Rush, Trans. A.S.M.E., vol. 65, 194 , pp. 279-286.

Contributed by the Fuels Division and presented at the Spring Meeting, Davenport, Iowa, April 26-28, 1943, of The American Society of Mechanical Engineers.

motion in the opposite direction to the whirl of the hot gases, with the result that quick mixing is effected when the air outside and the hot gases inside reach the end of the tunnel.

Today, heating by steam is limited by the extreme difficulty of obtaining steam boilers. A steam plant requires piping, valves, traps, and accessories, all involving large quantities of critical metal, and skilled labor for their installation.[3] In many areas, heating by oil or gas is prohibited by limitation orders. This leaves coal as the only available fuel, but its products of combustion cannot be mixed with the heated air, except in applications where contamination by fly ash or sulphur fumes would not be harmful, such as driers for sand and gravel, or coal.

There is thus at present a real demand for a reliable and efficient coal-fired heater which can supply air at temperatures up to 350 F, in which the heated air is always positively free from contamination; and which at the same time does not demand more than a minimum of critical material for its manufacture. If alloy steels capable of withstanding moderately high temperatures were still available, the problem would be simplified, but such alloys are more urgently needed for other war uses. The air-temperature demands in the majority of dehydrating and chemical processes seem to fall between 150 and 350 F. The lower range can easily be met with the standard type of heater described in the first paragraph of the paper and in general use for space heating. But for the upper range, namely, 350 F, modifications are required.

For a given output in British thermal units per hour, the weight or volume of air delivered at this higher temperature is only on the order of one fifth of that handled by the standard heater. The velocity of the air passing over the heating surface would be decreased in the same proportion, and the heat abstraction from the steel shell through which the heat is transmitted would be so reduced thereby that the shell would reach a glowing temperature, If made of ordinary carbon steel it would oxidize rapidly and fail in short order. To maintain the same air velocity with only one fifth the air volume would mean restricting air passages around the shell to an impracticable extent and increasing the friction pressure drop to such a degree that a multistage blower would doubtless be required instead of an ordinary fan for forcing the air through the narrow passages. In this dilemma, the solution was found in recirculating the air, that is, passing each unit volume of air not once but several times around the heating surface; thus about 5 times as great a volume passes over the heating surface as is discharged from the outlet, and this is the distinctive feature of the heater described in the present paper.

DEVELOPING THE RECIRCULATING AIR HEATER

A description of the stages by which the full development of this idea was reached may be of interest. The first installation in which the attempt was made to use the standard type of space heater for furnishing air at temperatures high enough for drying was in a paint-baking oven of a large tank arsenal.

Here the air was recirculated through the oven and back to the heater, and it was found that the heat-transmitting shell of the unit did not overheat even when the entering air temperature rose to 250 F. In this case, the fuel was oil, and the oil-burner control, which was of the modulating type, maintained just the fuel rate required for a predetermined outgoing-air temperature. Hence when the entering air was at 250 F, the fuel input was reduced to a comparatively low rate. Nevertheless, the fact that these heaters were in actual operation on the paint-baking ovens with apparent success seemed to indicate that the heating surface should be capable, when wiped by air at the standard velocities, even at higher than usual temperatures, of withstanding safely the heating effect of the flame. The heating surface, described in a previous paper,[4] was a steel shell formed with deep corrugations and having welded-on fins and deflectors.

It was decided to conduct tests (1) on an oil-fired heater and (2) on a coal-fired unit, to determine what rate of heat transfer could safely be used with this type of heating surface with large amounts of high-temperature air being recirculated after mixture with the incoming cooler air, maintaining velocities over the heating surface of around 40 to 50 fps, which had been found satisfactory in the coal-fired space heater.

The test of the oil-fired heater was conducted on a standard unit, which experience had shown to be capable of transmitting up to 1,650,000 Btu per hr, without overheating the corrugated shell, when used as a space heater, that is, with an air-temperature rise of about 70 F. This heater, a cross section of which is shown in Fig. 4, had a total heating surface of 444 sq ft, of which 200 sq ft was prime heating surface, comprising the deeply corrugated shell of the combustion chamber; 91 sq ft was the tube surface; and 153 sq ft was secondary heating surface, comprising fins and deflectors. The fins and deflectors, as shown in Fig. 5, are so designed that the air flowing along the corrugated surface at a velocity of about 50 fps is carried down into the valleys of the corrugations in a series of turbulent whirls which very effectively wipe the heating surface and prevent it from overheating, displace the stagnant or slow-moving layer of air adjacent to the metal in the valleys, and effectively transfer the heat to the air stream.

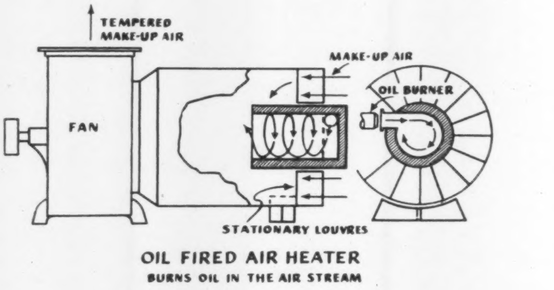

FIG. 3 MIXING-TYPE OIL-FIRED HEATER WITH ROTOFLAME EFFECT

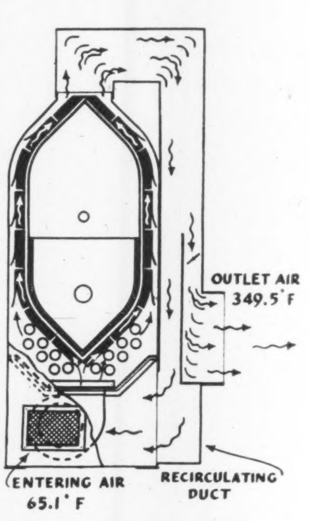

FIG. 4 OIL-FIRED HEATER, NON-MIXING TYPE, ARRANGED FOR RECIRCULATION

It will be noted in Fig. 4 that the lower half of the combustion chamber is lined with a thin monolithic layer of refractory. Metal hooks welded to the inner surface hold this refractory in position. Not only is heat radiated from the glowing surface of the refractory, but the latter, being thin, transmits quite an appreciable amount of heat by conduction to the corrugated metal surface at its outside. In this illustration will also be noted the circulating fans which blow the air over the tubes and the heating surface. An exhauster, mounted on the same shaft and driven by the same motor as the main blowing fans, removes the burned gases from the combustion chamber and produces therein the desired draft.

The greater part of the hot air from the top of the heater is recirculated as shown through a duct back to the inlet, where it mixes with the cool air which enters through grilles at the ends of the base of the heater. On its way to the fans, this cool air passes over the bearings, cooling them sufficiently. As a precaution, however, special ball bearings suitable for high temperatures were used, but with this exception the heater was standard throughout.

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[4] "Design and Performance of a Direct-Fired Unit Heater," by R. M. Rush and H. A. Pietsch, *Heating Piping and Air Conditioning*, 1942, p. 75.

RESULTS OBTAINED WITH TEST HEATER

In the test heater no attempt was made to insulate either the heater casing or the recirculating duct, and therefore a large radiation loss occurred. In a completed installation these surfaces would be well insulated, and from known coefficients of heat conduction and radiation it is estimated that this loss would not exceed 10 per cent of the heat output of the unit. Furthermore, in most cases this 10 per cent would be largely recovered, that is, in those cases where the heaters are installed in a plenum chamber from which the air to be heated is drawn, and where most of the heat dissipated from the casing is picked up by the air and helps to heat the latter. Because of this large radiation and unaccounted-for item, it is realized that the test results are not as convincing as would be desired; nevertheless they are given in Tables 1, 2, and 3, to demonstrate the performance of the fin-and-deflector type of heating surface made of ordinary carbon steel.

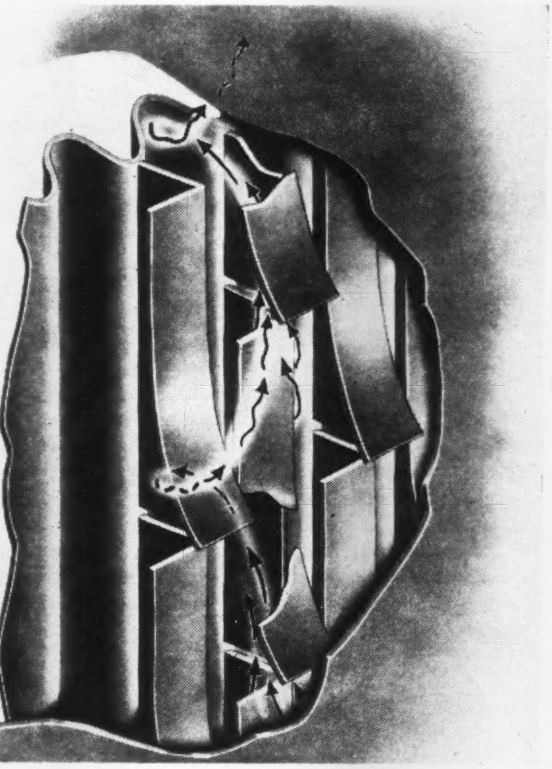

FIG. 5 FLOW OF AIR AS DIRECTED BY FINS AND DEFLECTORS

It will be noted that the average outlet temperature of the air was 349.5 F. This was attained without overheating the combustion chamber and with a heat transfer through the combustion chamber walls (since the heat later lost by radiation was also transmitted through this surface) of approximately 1,320,000 Btu per hr. The average fuel input was 11.55 gph and was set at this figure because preliminary tests had indicated that, when the fuel rate was increased to around 12 gph, the inner shell began to show slight color. The test seemed to indicate that, when the standard space heater is arranged to furnish 350 F air by means of recirculation, a heat-transfer rate of approximately 80 per cent of the normal space-heater rating is permissible.

TABLE 1 TEST OF OIL-BURNING RECIRCULATING HEATER

MEASURED TEST DATA

Date of test: February 23, 1943
Duration of test: 4 hr after stabilized conditions were attained

Oil burned, lb per hr	88.5
Specific gravity	0.922
Gross calorific value of oil as fired, Btu per lb	18722
Average temperature of air entering base of heater, deg F	65.1
Average temperature of air leaving heater, deg F	349.5
Average temperature of flue gases at heater outlet, deg F	673.1

ULTIMATE ANALYSIS OF FUEL OIL

	Per cent
Carbon	84.33
Hydrogen	11.95
Sulphur	2.48
Oxygen	0.79
Nitrogen	0.35
Moisture	0.10
Total	100.00

AVERAGE ANALYSIS OF DRY FLUE GASES AT HEATER OUTLET

	Per cent by volume
CO_2	13.30
O_2	2.95
CO	0.00
N_2	83.75
Total	100.00

TABLE 2 CALCULATED VALUES

Heat input in fuel oil, Btu per hr	1657380
Quantity of air supplied by heater at outlet (volume referred to 70 F), cfm	2409
Weight of air supplied by heater, lb per hr	10540
Heat delivered in air at heater outlet (average), Btu per hr	719341

TABLE 3 HEAT BALANCE

	Btu per lb of fuel	Per cent
Heat input in fuel oil	18722	100.00
Heat absorbed by air, heater outlet	8125	43.40
Heat loss due to moisture in fuel	1.3	0.01
Heat loss due to latent heat of water vapor formed by combustion of hydrogen in oil	1438	7.68
Heat loss due to moisture in combustion air	39	0.21
Heat loss due to sensible heat in dry flue gases	2332	12.45
Heat loss due to carbon monoxide in flue gases	0	0.00
Total losses accounted for	3810	20.35
Heat loss due to unconsumed hydrogen and hydrocarbons, radiation, and unaccounted for	6787	36.25
Total	18722	100.00

As the test had demonstrated that a recirculating heater of this type is practical, twelve such heaters, each rated at 1,000,000 Btu per hr output, were built to furnish 350 F air for reactivating alumina in a large dehumidifying project. In this case, the available fuel was oil, so in order to avoid contamination of the alumina, the products of combustion had to be kept separate from the heated air. The mixing type of heater (Fig. 3) therefore could not be used, and the recirculating heater was the logical choice.

All twelve heaters are located in a large plenum chamber in which the dehumidifiers are also placed. The heaters and their recirculating ducts will be carefully insulated, and the radiation losses such as they are will go into the room through which the air to be heated is drawn. As the losses will be only those in the flue gases, operating efficiencies between 70 and 80 per cent are expected to be attained.

COAL-FIRED HEATER ARRANGED FOR RECIRCULATING AIR

While the tests of the oil-fired heater successfully demonstrated the practicability of recirculation and its effectiveness in conjunction with the fin-and-deflector design of heating surface, a coal-fired heater presents some additional problems, and it was therefore decided to test a coal-fired heater arranged for recirculation, as shown in Fig. 6.

This heater was initially designed for air-temperature conditions not much different from the standard space heater, namely, 145 F temperature rise with entering air at minus 20 F, when delivering 1,363,000 Btu per hr with 8707 cfm (volume referred to 68 F, 50 per cent relative humidity). The tests could not be conducted under these conditions because, at the time of the test, the entering-air temperature was 60 F. The total heat supplied to the outgoing air during the test was 1,355,000 Btu per hr. But again the insulation of the heater and its recirculating duct had not been considered necessary, as the heater was installed in the plant of an ordnance manufacturer where heated air was required for some special purposes; and just as in the case of the oil-fired heater, a good portion of the total heat imparted to the air was lost through radiation and convection from these surfaces. Allowing for this, the actual heat transmission through and from the combustion chamber walls must have been in the neighborhood of 1,620,000 Btu per hr.

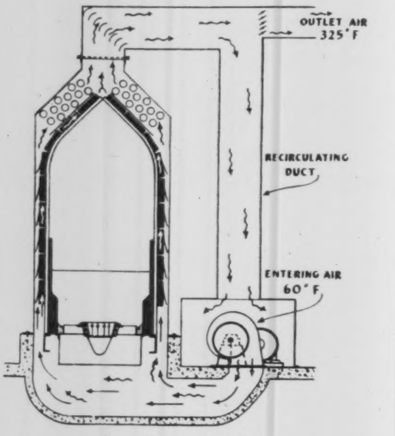

FIG. 6 COAL-FIRED SPACE HEATER, WITH RECIRCULATING DUCT ADDED

After testing the heater for approximately its design conditions, it was decided to test with a higher final air temperature. This was done by decreasing the amount of cold air drawn in and, correspondingly, the amount of warm air supplied to the outlet duct, while the amount of air recirculated was increased proportionately. The discharge-air temperature in this case was 325 F, with an inlet temperature of approximately 60 F, or a total temperature rise of 265 F. The test results are given in Table 4.

While the heat supplied to the outgoing air stream was somewhat less than 1,000,000 Btu per hr, it is evident from the heat balance that, if the heater casing and the recirculating duct had been well insulated, the figure would have been increased to about 1,425,000 Btu per hr.

TABLE 4 TEST OF COAL-FIRED RECIRCULATING HEATER WITH AIR HEATED TO HIGH TEMPERATURE

Date: February 20, 1943	
Approximate rate of combustion of coal, lb per hr	139
Approximate heating value of coal, Btu per lb	13870
Average temperature of make-up air entering fan, deg F	60
Average temperature of air leaving heater, deg F	325
Average temperature rise of air, deg F	265
Volume of recirculated air (referred to 70 F), cfm	7140
Volume of make-up air (referred to 70 F), cfm	3220
Volume of air passing over heating surface (referred to 70 F), cfm	10360
Average temperature of flue gases leaving heater, deg F	630
Carbon dioxide in flue gases	12.3

APPROXIMATE HEAT BALANCE

	Btu per hour	Per cent
Total heat input, in coal as fired	1930000	100.00
Heat supplied to air discharged at 325 F	922000	47.77
Sensible heat in dry flue gases	295000	15.28
Loss due to moisture in fuel	11000	0.57
Loss due to moisture in air and to unconsumed combustible	38600	2.00
Calculated loss by radiation and convection from surfaces of heater and recirculating duct	562000	29.13
Unaccounted-for (leakage, etc.)	101400	5.25
Total	1930000	100.00

The heater on which this test was made is a standard coal-fired unit having a simple screw type of stoker; the total heating surface is 820 sq ft, of which 340 sq ft of area is prime surface, 195 is tube surface, and 285 is secondary surface, composed of fins and deflectors. This heater had a maximum rating of 2,000,000 Btu per hr for use as a space heater. In the test, with recirculated air heated to 325 F, the heat transferred from the heating surface to the air stream was about 71 per cent of the heater top rating. In view of the characteristics of coal firing, it is considered desirable in both space and recirculating heaters to allow a materially larger area of heating surface for a given heat output than in the case of oil or gas firing, and this greater area is available in the coal-fired heater described.

CONCLUSION

It is evident from the foregoing that the recently increasing demand for higher-temperature air has led simply and naturally from the standard space heater to the development of the recirculating type adapted not only to oil or gas but to coal firing. The heater thus developed, requiring for its construction only materials which are now available, is likely to find wide application in food dehydration, chemical processing, and other industries requiring air at temperatures between 150 and 350 F.

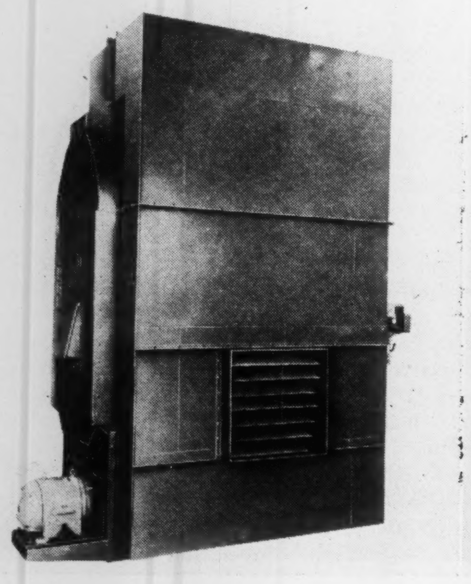

FIG. 7 HIGH-TEMPERATURE HEATER, RECIRCULATING AIR TYPE

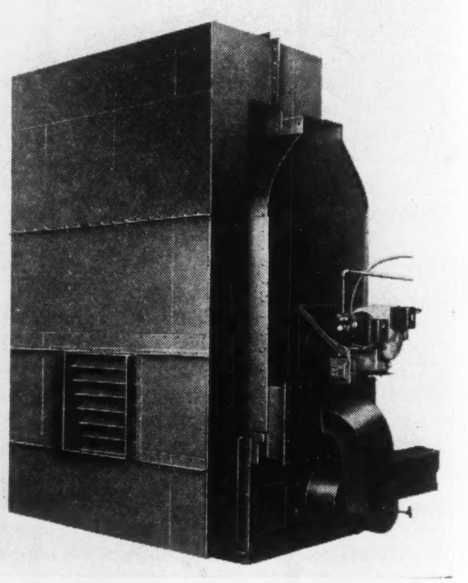

FIG. 8 HIGH-TEMPERATURE HEATER, RECIRCULATING AIR TYPE

PLASTIC DEVELOPMENTS *From* REDWOOD

By HARRY F. LEWIS

INSTITUTE OF PAPER CHEMISTRY, APPLETON, WIS.

RUNNING from a point 100 miles north of San Francisco, all the way to the Oregon-California border and near enough the Pacific Ocean to be hidden by the fogs which drift in almost daily from the ocean are the principal stands of the giant redwoods, *Sequoia sempervirens*. These majestic trees hold aloft their heads 200 or more feet above the forest floors. Some were noble trees when Columbus discovered America. Many more were there when King John signed the Magna Charta. So resistant is the wood to rot that fallen trees have lain hundreds of years in the muck of the forest with ferns and even full-grown redwoods growing over the half-buried trunks only to take their place on the production lines leading to the head-rig and trimmer saws.

As is well known, any lumbering operation results in a high percentage of trees going to waste. There are the woods waste such as lumber, branches, and tree tops; mill wastes, such as small dimensions, sawdust from head-rig and trimmer saws; bark, leaves, and even the cones. The Pacific Lumber Company of Scotia, Calif., has for many years been conscious of the waste. Development work has already resulted in the commercial conversion of sawdust to "Pres-to-logs," and bark to insulation and textile fiber.

REDWOOD RESEARCH PROJECT UNDERTAKEN

In a far-reaching program of conservation, about 5 years ago, the company instituted a long-term research project at The Institute of Paper Chemistry. As the first step in the project, the technical staff of the Institute carried out an intensive study of the chemical and physical components making up the redwood tree. A careful botanical study of the bark was carried out by a wood technologist; a fiber microscopist measured the length and width of the various types of fibrous materials both in bark and wood; analytical chemists analyzed wood from various places in the tree, such as sapwood, heartwood, old and new stumps, and roots. Determinations of extractive content were carried out on sections over fifteen to twenty feet all the way up the tree trunk. A plant chemist has studied the extractives in needles, twigs, and cones.

Following this fundamental investigation, application studies were then set up in the various fields in which the specific properties might be utilized. Many of these applications are still in their experimental stage.

The particular application study to be stressed in this paper is that of the redwood plastics. As an introduction into the plastic application, it is necessary to consider briefly the nature of the chemical components making up the wood. The principal constituents of the wood substance of redwood are much the same as those of other trees, namely, cellulose, lignin, and the large group of carbohydrates known as the hemicelluloses, including both pentosans and hexosans. The remainder consists of materials soluble in water and/or organic solvents, which give redwood its characteristic properties such as longevity, resistance to mold and bacterial attack.

Considering first the normal wood constituents, it has been demonstrated that redwood cellulose and lignin are much the same as the analogous products from other coniferous woods. The hexosans other than cellulose and pentosans were likewise studied critically. As far as can be determined these are normal products. As might be expected, there was a relatively greater ratio of cellulose/lignin in the newer wood, such as the sapwood, the reverse being the case in the older wood, such as the heartwood, stumps, and roots. The composition of extractive-free redwood is given in Table 1.

TABLE 1 COMPOSITION OF EXTRACTIVE-FREE REDWOOD, PER CENT

	Lignin	Pentosans	C and B cellulose	Poly-uronides	Cellulose/ Lignin
Redwood:					
Sapwood	33.8	12.9	56.0	4.0	1.65
Heartwood	36.4	12.0	53.4	3.9	1.46
Green stumps	37.4	9.9	53.3	2.7	1.42
Old stumps	37.3	10.7	52.4	3.8	1.40
Roots	37.6	8.4	55.4	3.2	1.47

Although the analysts have determined the differences in sugar units present in the various forms of redwood, the results will not be considered here since they apparently do not play too important a role in the plastics which are made from redwood.

The constituents with which we are primarily concerned are the extractives. These differ greatly both in kind and amount among the various samples of redwood, as is shown in Tables 2 and 3.

TABLE 2 DISTRIBUTION OF ALCOHOL-BENZENE AND HOT-WATER SOLUBLES IN REDWOOD FROM DIFFERENT SOURCES

	Sapwood	Lumber	Stumps	Roots
Per cent dissolved by				
Alcohol-benzene alone	1.6	7.3	16.3	28.9
Hot water alone	2.8	7.5	12.9	17.8

TABLE 3 RELATIVE AMOUNTS OF EXTRACTIVES AND EXTRACTIVE-FREE RESIDUES ACCORDING TO LOCATION

	Heartwood	Stumps	Roots
Extractives	10.2	20.1	32.3
Extractive-free residue	89.8	79.9	67.7

The chemical components of the various extractives are not so easy to enumerate. All have small amounts of ether solubles (less than 1 per cent). Consequently, the sums of esters, fats, oils, resin acids, and waxes must total less than that amount. The ether solutions contain a volatile oil having the odor of freshly cut redwood, a small amount of a wax, a considerable amount of amorphous red-brown material, and, in the case of heartwood, a crystalline substance which is termed "sequoyin."

The alcohol-benzene extracts yielded large amounts of reddish-brown noncrystalline substances difficult to separate and purify. Fractional crystallization was not effective using inert solvents. All extracts gave amorphous fractions, easily oxidized in alkaline solution to which they imparted a permanganate coloration, subsequently forming brown colloidal precipitates. The fractions were completely precipitated from

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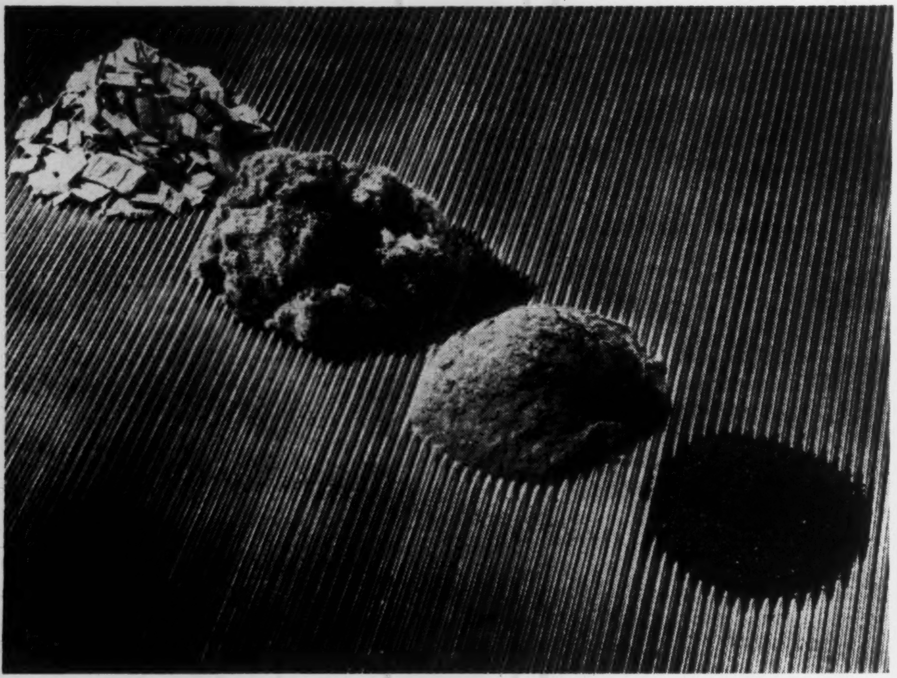
Contributed by the Wood Industries Division and presented at the Spring Meeting, Davenport, Ia., April 26–28, 1943, of The American Society of Mechanical Engineers.



STAGES IN THE PROCESSING OF NONCRITICAL PHENOLIC-TYPE THERMOPLASTICS FROM REDWOOD CHIPS

solution with lead acetate and gave colloidal light-brown precipitates with bromine water, reactions which are characteristic for the catechol-type tannins and their related phlobaphenes. Fusion with potassium hydroxide yielded catechol; hence the product, redwood tannin, is of the catechol type. A distribution of tannins and nontannins has been made for the hot-water solubles, Table 4. Recent tests made of other samples of redwood show that the tannin content of the bone-dry stumpwood will often go as high as 6 per cent.

TABLE 4 DISTRIBUTION OF TANNINS AND NONTANNINS IN REDWOOD

	—Hot-water-soluble—		As determined separately from alcohol extractions;
	Tannins	Nontannins	Tannins
Sapwood	0.2	1.5	0.2
Heartwood	2.6	6.9	4.1
Green stumps	4.1	7.9	4.1
Old stumps	3.3	5.8	3.8
Roots	7.1	7.8	7.8

A further breakdown of the alcohol-soluble components has been made, Table 5. Because of these differences in composition, it is necessary, in considering the utilization of the redwood wastes, to limit the waste converted to the one doing the particular job. Obviously, if we are interested in tanning with redwood, we would use rootwood or stumpwood if we could get it and not sapwood.

TABLE 5 DISTRIBUTION OF ALCOHOL-SOLUBLE COMPONENTS OF REDWOOD CALCULATED TO ORIGINAL BONE-DRY WOOD

	Alcohol extract	Phlobaphenes	Tannins	Cycloses	Reducing sugar
Sapwood	1.9	0.7	0.2	...	...
Heartwood	13.2	6.2	4.1	1.3	0.3
Green stumps	15.8	7.6	4.1	2.2	1.0
Old stumps	13.0	3.2	3.8	1.9	0.7
Roots	32.0	22.1	7.8	...	1.1

To complicate the picture yet further, the group word "tannin" may not necessarily refer to the same parent substance in the various fractions. The tannin in the cones, old stumps, and roots yields fine leather, while that in the ordinary heartwood conveyer waste is not nearly as satisfactory.

Incidentally, the rot-resisting properties of the redwood stem from this same tannin extract. When aqueous extracts of stumpwood, heartwood, and rootwood are prepared in concentration of 2 per cent and mixed with a nutrient medium made up of malt extract and bacto agar, the growth of the wood-destroying organism *Fomes annosus* is completely inhibited.

PRODUCING PLASTICS FROM REDWOOD

With this background, let us now consider the problem of producing plastics from redwood. Redwood, as such, in the form of wood flour is thermoplastic. It may be molded directly, without any added material, to give a product which resembles in appearance an article molded out of the conventional thermosetting molding powders. Because of poor flow characteristics and the fact that the product is not particularly water-resistant, molding redwood flour alone is not a commercial operation. Low flow means high pressure for molding; in this case about 5000 psi and 320 F being required to produce a simple disk. The degree of flow and nature of the product are related to the extractive content. The sapwood cannot be made into a molded article of any practical importance. Roots, on the other hand, give a somewhat more interesting product. Redwood flour can be improved in its molding characteristics by adding agents, or "plasticizers," which improve flow, such as glycerine in which the plasticizer is present to the extent of 10 per cent. An additional improvement is noted when a hardener such as hexamethylene tetramine is added. Under these conditions, it is possible to mold an article which is both strong and water-repellent. For example, we have made test pieces, having the following characteristics:

Impact, Charpy unnotched	1.03
Tensile, psi	6450
Flexural, psi	10433

from a molding powder of the following composition:

Redwood flour, per cent	91.5
Glycerine, per cent	3
Hexa, per cent	5
Condensation black, per cent	0.5

molded at 4000 to 5000 psi and 320 F. The principal disadvantage is the great pressure required for molding.

Redwood flour has a second use in plastics as an extender for the scarce phenol-formaldehyde resins. However, this use is not particularly satisfactory since the products lack the water resistance of the straight phenolics. It may be considered, however, for emergency use.

A molding powder of this type has been made from redwood flour and a phenolic resin in accordance with the following formulation:

Stumpwood flour, per cent	74
Durez 114, per cent	25
Calcium stearate, per cent	0.5
Carbon black, per cent	0.5

These ingredients are mixed for 90 min, milled for $1^{1}/_{4}$ min at 210 to 240 F, and then ground. The molding powder should be preheated for 2 min at 100 C. After curing at 150 C for 2 hr this product gives better impact and water resistance.

The material may be molded at 4000 psi and 310 F for 5 min. It is thermosetting and can be used in bakelite molds. Its strength values are as follows:

	Palco 198	Bakelite 3200
Impact	0.55–0.6	0.610
Tensile, psi	5300	6520
Flexural, psi	7500	8560
Water pickup, per cent in 24 hr	2.5	0.47
Molded density	1.37	1.356

REDWOOD PLASTIC PULPS

A second point of attack on the problem of utility of redwood wastes for plastic purposes has been based upon the discovery that redwood wastes may be cooked with steam at high pressure, whereupon the tannins and phlobaphenes are modified and combined with modified wood substance to yield a pulp which is much superior to redwood flour as a base for further plastic operations. The pulp, which looks much the same as chewing tobacco, can be molded alone. The molded pulp has the following physical characteristics, when molded at 4000 psi and 300 F:

Impact, Charpy unnotched	0.58
Tensile, psi	5480
Flexural, psi	7700
Water pickup, per cent	2.5 to 3

It has several disadvantages when used alone. For example, it is partially thermoplastic, and the molds must be cooled from 300 F, the molding temperature, down to approximately 250 F to eject. Furthermore, the product swells and becomes sticky when exposed at elevated humidities because of the presence of resins which are still somewhat water-soluble. Nevertheless, alone or mixed with a small amount of lignin or "Vinsol," a product results which has good flow and finish and moderately satisfactory physical characteristics. The strength of this molding composition is as follows:

Impact, Charpy unnotched ($^{1}/_{2} \times {}^{1}/_{2}$-in. pieces)	0.45
Tensile, psi	6700
Flexural, psi	8000
Water pickup, per cent in 24 hr (ASTM)	2 to 2.3

Many articles have been molded from the 95-5 basic formulation. The formula has the advantage of being cheap and available in large tonnage without the use of any critical materials.

Nevertheless, the thermoplastic characteristics of redwood pulp would hold the ready utilization of the formula down to emergency uses.

THERMOSETTING MOLDING FORMULATIONS FROM REDWOOD

This leads to the third phase of the research, namely, the production of thermosetting molding formulations. The thermosetting molding powder now achieved is the result of a series of interesting chemical reactions. The first involved the conversion of the tannins and phlobaphenes in the redwood to a resinous composition with the normal wood chemicals, as a result of its cooking operation. It was then discovered that these constituents could be further condensed up to the stage of thermosetting materials with a resinous material developed at The Institute of Paper Chemistry. This resinous material is the result of a polymerization of a by-product condensed in turn with formaldehyde. The resin and the redwood plastic pulp are then condensed together by milling in the presence of a catalyst to the desired point at which they will polymerize in the mold to yield the finished product under manufacturing conditions. The product has the following physical characteristics:

Impact, Charpy unnotched ($^{1}/_{2} \times {}^{1}/_{2}$-in. piece)	0.37
Tensile, psi	5000
Flexural, psi	6500
Water pickup, per cent	1

It will be seen that the strengths are not quite as high as those for the straight pulp, but the increase in resistance to water (and incidentally to acids) makes it much more interesting for commercial use. Its conversion to a thermosetting product means that conventional bakelite molds can be used.

In no sense can this be considered as the final step in the development. In the space of 6 years from the beginning of this effort, considerable progress has been made in indicating the direction in which the great woods waste from the redwood operation can be more effectively utilized. Further research will carry this development on to yet greater achievements.

ACKNOWLEDGMENT

This research project has been financed by the Pacific Lumber Company since its inception in 1936. The participation of the sponsor in the project has, however, been far from an academic one. Starting with the objective of developing a fundamental knowledge of its product, redwood, through the medium of research, the company has supplemented the work by utilization studies of its own including tanning, antioxidants, flotation agents, antiseptics, medicinal uses, textile, pulping, destructive distillation, hydrogenation, insect sprays, and other less important side lines. As a result, a wealth of fundamental and applied knowledge has been acquired, which has led to commercial applications in several fields.

The practical result of the plastics research has been the construction of a plant at Scotia, Calif., which has a maximum productive capacity of 2,000,000 lb of plastic pulp a month. The product has been absorbed in the manufacture of steering wheels on a commercial scale ever since the war cut off the supply of rubber and limited the supply of other plastics.

A FEW OF THE MOLDED PRODUCTS NOW BEING MADE FROM REDWOOD PLASTICS

Fuels Division of
THE CLEVELAND ENGINEERING SOCIETY

BY JAMES H. HERRON

CHAIRMAN, FUELS DIVISION, C.E.S.

THE newly organized Fuels Division of The Cleveland Engineering Society, in existence only since Sept. 28, 1942, has provided a new and unexpected vehicle for service to the general public. Concurrently, it has demonstrated an unforeseen value as an agent of good will for the society and as a practical aid to the agencies not only of municipal government but of the emergency arms of the wartime federal machine.

The Fuels Division is the realization of a dream which has been cherished for several years by a few engineers who, for purposes of this chronicle, shall remain nameless. Recognizing fully the accomplishments of the A.S.M.E., the A.S.H.V.E., and various other technical bodies in the field of fuel application and utilization, they felt there remained another and even broader arena for engineering activity in connection with fuel which had not yet been approached. Specifically, it lay largely in the realm of small plants, domestic and otherwise, which had hitherto been too small to attract engineering talent.

These small plants account for some twenty per cent of bituminous-coal consumption and thirty per cent of anthracite usage and are of great importance in the consumption of fuel oil and gas. By and large—and with but few and relatively unimportant exceptions—stove and furnace design in the small-plant field is unchanged since the days of Benjamin Franklin. Each manufacturer and installing contractor has been a law unto himself with authentic standards of both practice and performance nonexistent.

Examination of the field disclosed several lines of endeavor demanding attention. Principal among these was education of the public to the necessity for proper plant maintenance; and consideration of that problem disclosed a lack of properly trained men in the art of furnace repair. Misapplication of coal, whether as regards kind or size, was found to be a major source of waste and inefficiency, and this was noted to be a portion of the vast problem created by the infinite variety of coals and coal preparation offered by the thousands of mines of the country.

Lack of any bibliography on the subject of combustion and heat utilization in small plants was evident. Numerous publications have been made by several of the manufacturers of equipment, producers of coal, or institutions of learning, but they were isolated, unrelated, uncatalogued, and unappraised as to merit. Their collection and evaluation and the making of them available to an interested clientele offered itself as an objective.

Early in the planning of the activities of such a division it became evident that, owing to the peculiar conditions which surround each of the problems which offered themselves, a membership which was wholly technical would not be able to function with proper efficiency. The wide variety of coal available, the freight cost limitations which restrict certain coals to and bar them from certain areas, the variations in climate which govern regional acceptability in coals to a great extent, the variety in burning characteristics which exists in coals of similar analyses—all of these factors made it apparent that, regardless of technical education, men with practical fuel knowledge and experience were a necessary part of the picture.

On the alert to serve both the industry and the community, the directors of The Cleveland Engineering Society took all factors into consideration in planning for the new division. Taking advantage of the society by-law which permits the admission of nontechnical members with the grade of associate, the Fuels Division was authorized with the definite understanding that its ranks would be open to men of good repute who are engaged in the production, distribution, and utilization of fuel as a business. All then members of the society were told of the proposed new division and were invited to participate therein at their pleasure.

Formal organization of the division was effected at a meeting on September 28, with eighty members and prospective members present. By-laws were adopted which declared the objects of the division to be "the promotion of efficiency and economy in the utilization of all kinds and qualities of fuel for the benefit and welfare of the community through: (*a*) Study in all of their aspects of the merits of all systems or methods of fuel utilization; (*b*) study and promotion of the elimination of air pollution from the application of fuel; (*c*) promotion of public knowledge in the use of fuel without regard to type, kind, or quality; (*d*) collection and study of published information of character pertaining to domestic and commercial application of fuel."

An executive committee of fifteen is prescribed which, to assure impartiality as between fuels and equipment, must include representation from each of the following industries: fuel gas, fuel oil, coal production, the railroads, marine transportation, heavy equipment, light equipment, plant construction, fuel retailing, electricity, architecture, and education.

Recognizing the importance of a properly integrated program, it was determined to devote the first year of the division's life to a series of meetings at which various phases of the problem of fuel would be discussed, with the thought that such meetings would develop the actual and definite lines of activity which the division might best pursue.

Right there the swift movement of current events began to shape the month-to-month activities of the division and to demonstrate its definite value to the society and to the community. October was devoted to an exposition of the fuel outlook for the Cleveland area in the war winter just ahead. In November, study was devoted to statistics on gas, oil, and coal utilization in the Cleveland metropolitan area. In January an examination was made in the purposes and trends of research in coal utilization. February's subject was "Fuel Problems in the War," and March witnessed a round-table on the subject, "Coal in 1943."

Each meeting was addressed by men of national standing in their respective branches of the industry. All meetings were progressively well attended. Further, the interest generated

(*Continued on page 520*)

MAINTENANCE *of* ELEVATOR HOISTING MACHINES *and* BRAKES[1]

Elevator Service Bulletin No. 4[2]

II ELEVATOR HOISTING MACHINES AND BRAKES[3]

1 CONSTITUENT PARTS OF MACHINE

ELEVATOR machines generally consist of a motor (with or without gearing), brake, and drive sheave or drum, with necessary bearings and shafts assembled on a bedplate or base.

(*a*) *Inspection of Base.*

2 The machine base should be checked for cracks or broken lugs. Defective bases should be repaired or replaced.

(*b*) *Alignment of Machine.*

3 It is important that the base and assembly be in correct alignment. If there is any evidence of misalignment, the manufacturer should be consulted.

2 OUTLINE OF WEEKLY MOTOR INSPECTION

(*a*) *Oil Level.*

4 Check oil level. An excessively high or low level may cause operating difficulties. Oil should be of a grade recommended for the equipment by the motor manufacturer.

(*b*) *Oil Rings and Chains.*

5 Check oil rings and chains to see that they revolve freely. Chains should be examined for wear to be sure that they have not stretched to the point that the chain will touch the bottom of the oil reservoir.

(*c*) *Commutation.*

Check commutation as follows:

Brushes and Brush Rigging

6 Brush holders must clear the commutator and be securely fastened on the holding stem. Flexible leads should be securely attached to the brush and brush holder. Spring tension on the brushes should be just sufficient to hold the brush in contact with the commutator without chatter or vibration. Spring tension on individual brushes should be equalized by using a spring balance. Excess pressure causes rapid wear on the commutator and brushes. Brushes that do not make full contact with the commutator should be seated with fine sandpaper. Emery paper should not be used, as emery is a conductor and may cause damage. Excessively worn or defective brushes that cannot be properly reseated should be replaced with the grade and size of brushes recommended by the original motor manufacturer. New brushes must be properly seated. If, after properly adjusting brushes, there is still excessive sparking, a motor serviceman should be called in, as the use of abrasive stones, undercutting of commutator, or adjusting of brush spacing and setting by inexperienced mechanics may result in destruction of electrical equipment.

3 OUTLINE OF ANNUAL MOTOR INSPECTION

(*a*) *Motor Bearings.*

7 Examine motor bearings. If wear is excessive, replace bearing.

(*b*) *Oil Reservoirs.*

8 Drain oil reservoir, flush, and refill.

(*c*) *Pole Pieces.*

9 Check fastening of pole pieces.

(*d*) *Motor Windings.*

10 Examine motor windings. If necessary, have repairs made by competent motor serviceman. Check for loose terminals.

(*e*) *End Play.*

11 Check motor for end play. If insufficient or excessive, the condition should be corrected by a competent elevator mechanic.

(*f*) *Fastenings.*

12 Tighten loose bolts, keys, setscrews, etc., in fixed and rotating parts of motor.

(*g*) *Couplings.*

13 Tighten loose bolts, keys, setscrews, etc., in couplings. Defective fastenings should be replaced.

4 BRAKE INSPECTION

(*a*) *Types of Brakes.*

14 Elevator brakes are, generally, electrically or mechanically released. The mechanically released brakes are usually confined to elevators with hand-rope operation.

(*b*) *Brake Clearance.*

15 When in the released position the brake drum should run free of the brake shoes. The clearance will vary with the type of machine, but should, in all cases, be kept as low as practical in order to insure smooth brake operation and prevent damage to equipment, such as that due to excess heating with alternating-current brakes. This requires the brake drum to run true. Brake shoes should apply evenly to the drum. It is important that the brakes should be readjusted for uniform bearing shortly after brakes have been relined or other adjustment made to the brake shoes. This is particularly important in the case of automatic operation.

(*c*) *Periodic Adjustment.*

16 Brakes should be adjusted periodically to keep clearances to a minimum and to keep the bearing of brake shoes uniform. Brake pins should be examined for wear and be

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[1] Prepared by the Executive Committee for the Safety Code for Elevators, Dumbwaiters, and Escalators of the American Standards Association.

[2] Bulletin No. 1, Elevator Wire-Rope Maintenance, appeared in MECHANICAL ENGINEERING, February, 1943, pp. 110–112; Bulletin No. 2, Maintenance of Elevator Mechanical Safety Appliances, in MECHANICAL ENGINEERING, May, 1943, pp. 350–352, 359; Bulletin No. 3, Maintenance of Elevator Hoistway and Car Enclosures and Equipment, in MECHANICAL ENGINEERING, June, 1943, pp. 433, 434, 439.

[3] Part I, Introduction, omitted from this installment, is substantially the same as appeared in connection with Bulletin No. 1.

replaced if necessary. All pins and bearing surfaces should be kept well, but not excessively, lubricated. Solenoid cores and sleeves should be kept free from gummed oil to assure proper lifting and setting of the brake.

(*d*) *Brake Drums.*

17 Oil, grease, and rust should be removed from the brake drum. A cracked brake drum must be replaced. Two-piece (split) brake drums must be examined periodically to make sure that the two halves are in proper alignment.

(*e*) *Brake Holding Power.*

18 Brakes should be set to stop at least 120 per cent of contract load, but excessive spring pressure is undesirable.

(*f*) *Brake-Lining Maintenance.*

19 To prevent damage to brake and loss of braking power, brake linings should be examined to see that they are not wearing to the point where rivet heads or wire reinforcement may come in contact with the drum. Leather linings should receive an occasional application of neat's-foot oil. Do not use mineral oil. Where grease or oil has reached the brake mechanism, the linings should be thoroughly cleaned with a suitable solvent, and, if necessary, the surface slightly roughened with a steel brush.

5 GEARING

(*a*) *Lubrication.*

20 Elevator gears must have adequate lubrication if reasonable life is to be secured. Ordinary lubricating oils are not satisfactory for this purpose; only lubricants recommended by the elevator manufacturer should be used.

(*b*) *Gear Alignment and Wear.*

21 Gear alignment should be checked periodically. Bolts holding the ring gear to the spider must be kept tight. When a worm and gear are correctly aligned, the wear on the tooth surface is practically uniform and distributed equally on both sides of the center line of the gear. In case of uneven tooth wear or in case of excessive backlash in starting and stopping, an elevator company, preferably the one making the original installation, should be consulted, as the method of making adjustments varies from manufacturer to manufacturer.

6 DRIVE SHEAVE AND DRUM MAINTENANCE

(*a*) *Drive Sheaves.*

22 Drive sheaves should be examined for cracks[4] and for wear of grooves. The bolts holding the sheave rim to its spider should be checked periodically to be sure that they are all tight. The effect of worn grooves and misalignment was discussed at some length in Circular C441. Bearings should be examined most carefully for play of the shafts.

(*b*) *Winding Drums*

23 Winding drums should be examined for cracks or other signs of failure and for worn ridges between rope grooves. Anchorage of ropes inside of the drum should be checked, and if the ropes are long enough, it is desirable, in addition, to secure the ropes around the drum shaft. Drum machines are also equipped with a slack-cable mechanism. This should be examined and tested for proper operation.

7 INSPECTION OF BELTED MACHINES

24 On belted machines the condition of the belt or belts should be examined to see that they are not cut or torn and that there is no appreciable slippage. Belt-shifter forks should be examined for wear. If belt-shifter parts are badly worn or belts are cut or torn, they should be replaced. Where belt machines are suspended from the ceiling, the suspension members and their anchorage should be thoroughly examined and those that are defective should be replaced. Machine-holding bolts should be checked for tightness.

III INSPECTION OF OVERHEAD SHEAVES, BEARINGS

25 Overhead sheaves should be checked for cracked rims or arms and for worn rope grooves. A method of testing for cracked sheaves is outlined in The Inspectors' Manual.[4]

IV INSPECTION OF MOTOR GENERATOR SETS

26 Individual checking of motor generator and exciter will be similar to that already detailed for hoisting-machine motors

Fuels Division of The Cleveland Engineering Society

(*Continued from page 518*)

and the influence gathered unto the division was such as to place it in a totally unexpected position in public affairs.

For example, the federal officials charged with the obligation of converting fuel-oil-burning plants to coal, becoming cognizant of the engineering talent and industrial knowledge obtainable through the ranks of the division, are using its resources in many cases where the exactly proper decision regarding a conversion is a matter of dispute. Industrial plants, faced with difficulty in finding proper sources of fuel supply, are calling on the division for assistance. Associations of fuel users, for example, the Laundryman's Institute and the Apartment House Owners Association, have sought group counsel on fuel matters.

Western Reserve University, seeking to modernize its curriculum by the offering of courses fitted to prepare graduates for practical sales work, has accepted the advisory help of the division in the planning of a course in fuel salesmanship. John Huntington Institute has indicated its willingness to co-operate with the division in offering a course in furnace maintenance. Both of these events open further the door of educational reform which seems to be needed with the progress of science and technology in business and social life.

The city administration, stimulated by the response met by the Fuels Division, has organized a Mayor's Committee on Fuel Conservation for War, officered and staffed largely from membership of the division. These various activities culminated last month in the utilization by the Department of the Interior of the joint sponsorship of the Fuels Division and the Mayor's Committee of a meeting where the Government's 1943 program for the summer buying of coal was launched in the Cleveland area.

It is a demonstrable fact that one of the weakest links in the American chain of commerce and industry is in the application of fuel. Further, engineering societies everywhere are seeking new fields of public service; new media through which the engineer as an individual and in a group may contribute more to common welfare; new means of selling themselves to the, as yet unaffiliated, professional man as the logical channel for the development of his talents for the common good.

The Fuels Division of The Cleveland Engineering Society, only seven months old, boasts of membership of 100 and a full staff of officers and directors competent to represent the industries whose interest lies therein. Young as it is, it enjoys a history of accomplishment that would be a proud asset to any serious-minded group with a decade of existence. It has provided a stimulus to the society of which it is a part that amounts to an invaluable contribution to the profession. It wields a conservative influence in the political, commercial, and social community that adds materially to its welfare and security.

Its progress presents a challenge to similar groups in similar and even lesser communities to perform a parallel service.

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[4] See "The Inspectors' Manual," published by The American Society of Mechanical Engineers, 29 West 39th Street, New York, N. Y.

ENGINEERS' RESPONSIBILITY *in* CIVIC AFFAIRS

By D. ROBERT YARNALL

YARNALL-WARING CO., CHESTNUT HILL, PHILADELPHIA, PA.

SOMEONE casually reminds us: "A man is born a citizen and he may become an engineer."

We who are members of The American Society of Mechanical Engineers have had for years held before us in our Code of Ethics this advice:

> It is the duty of every engineer to interest himself in the public welfare and to be ready to apply his special knowledge, skill, and training in the public behalf for the use and benefit of mankind.

Today, in wartime, engineers are more fully engaged than in any time in our history. Their loyalty, ability, and industry are universally recognized and generally commended. Planning for their training and their performance was done years ago.

PLANNING IN EDUCATION NEEDED

As we consider together "Engineers and Civic Responsibilities," I assume we are looking well ahead and beyond the war years. We all know that the stern realities of war probably will not allow experimentation with new educational technique as applied to the present going system. But just as we are at present engaged in postwar planning in the field of international relations as well as in the industrial and economic fields, so should we engineers be planning well ahead in our educational field, particularly as it relates to engineers' responsibility in civic affairs. We should remind ourselves that postwar planning must not be an escape from present responsibility. Yet our government officials lead the way in urging us to look toward and plan for the peace. The Secretary of State, in a notable address, has presented a striking outline of the structure of peace. He calls for swift and effective action at the close of the war to relieve human suffering in war-devastated countries. He hopes for the pursuit within nations of political liberty, economic security, and social justice for all alike. He states the necessity of co-operation of all nations, including the United States, in establishing a genius to reduce armaments, to settle disputes by peaceful means, to reduce trade barriers, and to provide equal access to raw materials. "No nation," said the Secretary, "will find this easy. Neither victory nor any form of postwar settlement will of itself create a millennium . . . . . . The vision, the resolution, and the skill with which the conditions of peace will be established and developed after the war will be as much of a measure of man's capacity for freedom and progress as the fervor and determination which men show in winning the victory."

We in the engineering profession and particularly you in the S.P.E.E. concerned with the right development of engineering education must be mindful of our responsibility for our part in this high calling.

Everyone expects engineers to design and build the sinews of war. Can they count with equal confidence upon them as citizens after the war not only to help beat swords into plowshares and spears into pruning hooks, but to help insure "that this nation under God shall have a new birth of freedom? What is freedom for us? How secure is it?

CAN WE RETAIN OUR FREEDOM?

May I tell you a story of a personal experience in Germany? I had been sent to Germany during those days when the democratic Weimar Constitution was operative, in 1920, to plan for the distribution of American food to the undernourished children and mothers and was at first assigned the job of organizing the feeding in the southern cities, with headquarters at Frankfurt am Main, including Stuttgart, Fortsheim, Carlsruhe, Mannheim, Heidelberg, Darmstadt, and as far north as Kassel. In all of these districts I made intimate friends among those public-spirited Germans who were concerned with distribution of relief to children and mothers who suffered most by reason of the continued blockade which actually lasted long after the Armistice was signed in 1918.

Years later, but before Germany attacked Poland, I was again in Germany on another mission, and while there I went down to Frankfurt to look up some of these old friends, to find out what was their present attitude of mind, particularly toward the political regime. An old doctor friend who had been particularly helpful in the *Kinderspeisung* days of 1920 asked me to spend Sunday afternoon with him and his wife and daughter in the Palm Garden. This was indeed welcome to me, as I thought I would be able to get from him, one of the local strong men of Frankfurt, the truth about Germany. We had a delightful afternoon under the trees listening to the music and talking about old times. I found that the doctor's wife was a violent Nazi; she could not understand why we "sensible Americans" did not understand the glorious new Germany which had come as a result of the National Socialist political victories. Their daughter, a girl of 18, a Hitler *Jugend*, was also an enthusiast for the new regime, saying that at last there was a future ahead for the young people of Germany and also a great future ahead for the Reich. At last Germany was taking her rightful place among the leading nations of the world. But all of this time I could not get an important word from the doctor. He questioned me a great deal about America and our political trends, about lynchings and kidnappings, as well as about the third-term possibility; but not a word could I get from him about his judgment of Nazi Germany. The afternoon wore on and the musical program came to an end and one by one the occupants of the tables left the Garden. Finally we arose and as the mother and daughter walked on ahead down the aisle, the doctor took me by the arm and said, in a low voice, when he was assured that no one could hear: "One thing in America you must never lose—you must never lose the Letter to the Editor."

He knew that Germany had sold her birthright for a mess of pottage. They had gained Nazism with its "Ein Reich, Ein Volk, Ein Fuehrer," but with this gain, freedom of speech, freedom of the press, freedom of religion had flown out the window.

How may we make more secure our freedom to write our "Letter to the Editor?"

May I repeat, "A man is born a citizen but he may become an engineer." Are we who have chosen engineering endowed by birth with "good citizenship" characteristics? Alas, far from

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An address before the Middle Atlantic Section of The Society for the Promotion of Engineering Education, Haverford College, Haverford, Pa., May 8, 1943.

it. Somewhere along the line with the help of good environment and sound training there must be built in us a sense of concern, a social conscience, that will not be satisfied with personal success within the bounds of our profession, desirable as this is, but will drive us on and out *with other citizens:*

(*a*) To carry our share of the burdens of world sufferings.

(*b*) To assume our constructive part in responsibility for good, wholesome government.

(*c*) To help in making secure those precious freedoms, among them the right without fear to write our Letter to the Editor.

In these last days, out of the clear blue, comes the *New York Times*' disclosure on the apparent inadequacy of the teaching of American history as based on the survey of 7000 freshmen in 36 universities. In time I have no doubt correctives will be applied to the criticized educational system which will better these percentages. I doubt, however, whether the engineering schools can count on secondary education to prepare freshmen in American history uniformly and thoroughly so as to make sure that in any test 75 per cent, at least, will answer that freedom of speech, freedom of the press, freedom of religion, trial by jury, and right of assembly were five of the freedoms guaranteed to the individual in the Bill of Rights.

Do you remember this warning in 1940, even before we were in the present war, by Hale Sutherland?

> The time is ripe, however, for acceptance of our insistence that the engineering schools establish a humanistic core of study, substantial and dignified, extending through all the years of the present programs, a core of study which will acquaint the student with the organization and operation of all the major elements of our democracy, its social, economic and political aspects.

In 1940, were the engineering faculties of colleges and universities represented here this afternoon conscious of the inadequacy of freshman preparation in United States history and the fundamentals of our form of democracy? Perhaps these things were known, but you thought it should be the concern of other faculties. You were more than absorbed with the great task of getting over to recalcitrant freshmen the math, chemistry, physics, descriptive geometry, kinematics, and other subjects which are the backbone of our profession.

Someone always suggests that this broader subject matter should be presented in two years of college work preceding the four years of technological curricula. You know this proposal has not won acceptance. No, I am sure the answer is not to be found in a longer course.

All citizens must have responsibility for our democracy, engineers no more and no less than other citizens. We should all highly resolve never to leave the country in the hands of any but the most competent.

Experienced teachers tell us "that it is more or less difficult to make a group, either young or old, loyal to an abstract ideal which is not integrated with their greatest interest, and in the case of engineers, through the vehicle of their own chosen profession."

Most young men are anxious and willing to contribute to the public good; naturally they would do best through the medium of their professional interest and training.

May I make a plea here and now for this core of study "substantial and dignified" extending through all the four years of our engineering courses—courses which will teach the essential elements of our democracy. I would have the standard of performance just as high in this core of study as in thermodynamics or calculus, and satisfactory completion just as essential for graduation.

SPIRITUAL VALUES NEED CULTIVATION

May I make another plea to you very wise and experienced educators. Please do not be indifferent to spiritual values in life, and *please don't "cold shoulder" religion!* In speaking of religion here we are not thinking of narrow sectarianism, but rather in broad, deep, all-inclusive, and personal terms.

Someone has said, "College young people are largely spiritual and religious illiterates, fatally ignorant in that all-important sphere of understanding which supplies *the binding element* in our complicated social order."

Madame Chiang Kai-shek said the other day, in one of her impressive speeches:

> We live in the Present
> We dream of the Future
> But we learn eternal truths from the Past.

With the press of many duties and responsibilities in college we are all conscious of the tendencies to crowd out spiritual and religious interests. Do you remember the experience of Brother Lawrence?

Resolving to devote himself to the service of God, he entered a monastery, but instead of spending his time in meditation and psalm-singing, he was sent to the kitchen, "being a dull and stupid fellow," to cook for the rest of the community. He was greatly cast down; how could he practice the presence of God in a noisy room with people rushing about all shouting for different things?

Then came the answer: "Nothing is easier. I have but to turn the cake in the pan for the love of God."

He learned to offer up every ordinary humdrum duty as an act of worship, and thus the kitchen, not the cathedral, produced one of our finest Christian classics.

We engineers have all so worshipped the specialization complex and the bread-and-butter side of engineering that we have missed the great chance to help make secure the better world we are now all desperately demanding. We have ignored "this binding element" in our complicated social relationships, saying to ourselves and our friends, "Let us get on with our profession."

You decided to hold this conference at Haverford College. You are now on the campus of one of the important Quaker institutions of learning in America. One of the basic elements in the Quaker faith (and I believe this is also held by other faiths) is the conviction that there is that of God in every man—the belief in the sacredness of human personality—the belief in the direct revelation of God to man without intermediary—the Inner Light, as they call it. This religious element in life may be the guide to conscience, may be the driving force which will make men responsive to the demands of democracy.

We engineers have too often passed up religion as an emotional element in life, saying that it has little or no place in engineering education—that this is the responsibility of others.

I am one of these engineers who believe with Dr. Richard Cabot, in his "What Men Live By," a book much read during and after World War I, that there are four essential elements in the well-rounded life—work, play, love, worship.

No matter how perfectly we plan this core of study designed to build up a sense of civic responsibility in our engineering graduates, it will not be completely effective unless or until that Divine discontent within him drives him out and beyond the narrow confines or boundaries of his profession, and compels him to use his engineering gifts to work with others for the good of the community of which he is a part.

I am not suggesting that the engineering school, much less this "core of study," should assume the Sunday-school function.

On the other hand, I am sure our colleges and universities must assume more and more responsibility for religious instruction and not relegate it completely to the student Y.M.C.A. or the more safely remote divinity school.

A dean of one of the well-known and respected engineering

(*Continued on page 524*)

MANUAL *for* DISCUSSION-TYPE MEETINGS

THE necessity of conserving time of engineers has made it desirable for The American Society of Mechanical Engineers to suggest and adopt, in certain cases, new methods for presenting technical information to its members. One such method is that of conducting discussion-type meetings. This type of session enables people who have interesting information, and insufficient time to assemble it in paper form, an opportunity to present such information. It is intended that such discussions would augment rather than replace the formal papers which now form the record of the Society's activities.

The purpose of this Manual is to present some guiding principles which may be of use to those individuals selected to act as chairmen for discussion-type sessions. For ease in reference, the Manual has been divided into a number of sections dealing with various phases of this subject.

PURPOSE

The purpose of any technical meeting of the Society is to give information to its members on a specific subject. The aim of the discussion-type meeting is to do this informing by using a method which requires minimum preparation time, pools all of the experience and current timely knowledge of the group, and is stimulating and interesting to those in attendance.

TYPE OF MEETING

The discussion-type session may take a number of different forms and can be used with marked success for small groups who may sit around a table, as well as for large groups requiring an auditorium. Two types of discussion procedure lend themselves well to engineering subjects. These are the round-table type and the jury-panel or panel type of meeting. Both procedures will be referred to throughout the manual. Other types of meetings might be planned, such as the "Information Please" question-and-answer type, if the subject matter warrants but, in general, they are not as productive of discussion as the two types mentioned.

Round-Table Discussion. The round-table type of discussion is directly under the supervision of the chairman of the session who, with a minimum of participation on his part, develops and directs discussion from those in attendance. The discussion should be made to follow items in a prepared agenda with which members of the audience are familiar.

This type of discussion meeting is the one with which people are perhaps most familiar, because of its frequent use. It is well suited for sessions with smaller groups where those present are familiar with the subject under discussion. It lends itself well to the less formal type of meeting which is more conducive to discussion.

The chairman, it is assumed, is familiar with the subject and with the background and connections of those in attendance so that their knowledge can be utilized and pooled.

It is usually a good practice on the part of the chairman, sometime before the meeting, to ask several persons in the group to prepare to discuss phases of the subject in the event that the meeting tends to lag. Every effort should be made to prevent the discussion from assuming a question-and-answer status. If, however, it is impossible to avoid direct questions, the leader should endeavor to have answers come from those in the group.

Panel Discussion. The panel type of discussion is recommended for groups containing over 50 to 75 engineers. The discussion, all under the direction of the chairman, is divided into two parts. The major portion is contributed by members of the panel while the remainder is added by those in the audience. The chairman must outline and organize the panel contribution with the panel members prior to the meeting to insure that the subject will be properly discussed and that the discussion will not become sidetracked or monopolized.

The panel is composed of four to six, or more, persons who have been selected because of their knowledge of the subject or subjects under consideration. They are chosen to represent all major viewpoints of the audience; they should be a good cross section of it. Under the direction of the chairman, and in front of the audience, they discuss the subject among themselves for the benefit of those in the audience. Persons in the audience are not allowed to interrupt this portion of the program but are given an opportunity after the subject has been covered by the panel members or after a certain period of time.

The chairman serves as co-ordinator to stimulate discussion between members of the panel and the audience, but he should not inject himself into the discussion. He should rather offer his ideas in a manner so that they are then discussed by those present.

This type of meeting can be boring and tiresome if the panel members are allowed to make a series of 10- or 15-minute speeches. To prevent such a trend, it should be the primary function of the chairman to see to it that the panel members interrupt each other at frequent and appropriate intervals during the period allotted to them for discussion.

This is a feature of the panel-discussion meeting too often misunderstood. The panel members are present to discuss the subject and not to give a series of talks.

STEERING COMMITTEE

In each division of the Society where the use of the discussion-type meeting is contemplated, the appointment of a steering committee is recommended. It will be this committee's duty to choose subjects for discussion, select the chairman, and aid him in preparation for the meeting. The committee would be distinct from, but co-ordinated with, the papers or program group and would be concerned only with the success of discussion-type meetings.

THE CHAIRMAN

The success of the discussion-type session is almost wholly dependent upon the selection of a proper chairman. He should be reasonably well informed on the subject, acquainted with at least a portion of the engineers in the audience, and have some of the attributes of a good public speaker, being able to think while on his feet and to be at ease before a group. He must remain neutral during any discussion and be able to conduct the meeting with tact so that a maximum of discussers participate to the exclusion of a few who might otherwise monopolize the meeting. He also must be able and willing to devote sufficient time in preparation for the meeting.

DISCUSSION SUBJECTS

The selection of the discussion subject is an important phase having to do with the success of the discussion-type sessions and is dependent on several factors. Group discussion is successful only when the topics considered are of vital current interest and closely associated with the experience of the group members. For a specified subject, therefore, it is necessary that engineers with appropriate interest and background be available.

The scope of a discussion topic also should be considered. In general, it is better to discuss one or several parts of a subject thoroughly rather than merely to skim over a number of phases.

Prepared by the Committee on Professional Divisions of The American Society of Mechanical Engineers, with the co-operation of R. M. Van Duzer, Jr. Mem. A.S.M.E.

Once a subject has been selected for the panel-type session, the chairman should discuss an outline of the topic and the discussion procedure with his panel members. Each member should be assigned certain topics on which he is to be prepared to open the discussion. For the round-table meeting, an outline of the subject should be submitted to interested engineers who should be in attendance inviting related items which they may be prepared to discuss or on which information is desired. Certain of these individuals, selected prior to the meeting, should be prepared to discuss different phases of the subject.

MEETING ARRANGEMENTS

It is important that consideration be given to the physical comfort of the audience. The room should be large enough for the expected crowd, ventilation should be adequate to care for smoke, and the chairs should be comfortable, the more so the better. For a round-table meeting, the seating arrangement should be as nearly circular as possible. The seating for the panel-type session should be so arranged that it is possible for the chairman and panel members to be heard without the use of a public-address system. A raised platform or stage may be used to good advantage so that the audience may listen to and observe the panel proceedings without discomfort. The chairman and panel members should be seated at a table.

A blackboard always should be provided, but the use of projection equipment should be discouraged because of the time usually required for its use.

ANNOUNCEMENTS AND RECORDS

In addition to the general publicity given to discussion-type meetings in published programs of the Society, detailed outlines of discussion subjects should be sent to interested members and guests. The size of the audience should not be the criterion of the success of this type of meeting, but rather the amount of productive discussion which results.

The matter of written records and the manner in which they are to be obtained should be left to the discretion of the sponsoring group. In general there should be no attempt to obtain a formal record of the meeting by the recorder or a special reporter because of the deterring effect it will have on free discussion. If a record is desired it should be prepared from notes kept by several persons selected for this purpose, prior to the meeting. In such a write-up, no names should be associated with the discussion.

CONDUCTING THE DISCUSSION

Once the meeting is organized and under way it is necessary for the chairman to carry on. He should observe the following points:

(1) The chairman should make certain that the audience is acquainted with the discussion subjects. Printed or typed sheets, available at the door, are recommended; however, a blackboard tabulation or a printed poster prominently displayed is satisfactory. Any changes in such a list should be announced at the start of the meeting.

(2) The chairman should detail the manner in which the meeting is to be conducted. If a panel-type meeting, he should describe the procedure to be followed in discussing each subject, that is, the major portion of the discussion will come from the panel with the remainder contributed by the audience.

He should introduce the members of the panel.

He should request all discussers from the audience to identify themselves.

He should announce that no written record of the proceeding is to be kept.

(3) The chairman should define the purpose of the discussion and, throughout the session, hold all contributions to that purpose. In the majority of cases, the purpose will be to provide an exchange of information.

(4) The time schedule to be followed for discussion of the various subjects should be given to the audience. Such a schedule, however, should be flexible to provide for those items provoking the most discussion.

To insure that all scheduled topics are covered, the chairman should have a watch on display to which he can refer.

(5) The chairman should prevent any speeches over two or three minutes in length. This is important to maintain the interest of the group.

(6) If a panel discussion is being held, the panel members should freely discuss the subject with a minimum of "leading" by the chairman. The discussion should be spontaneous.

(7) An intermission of five or ten minutes should be provided for "stretching" if the meeting is two hours or more in length. The physical comfort of the audience is important.

(8) The chairman should keep enough notes to that he can briefly summarize the discussion at appropriate intervals or before passing on to the next topic. This is not difficult to do and will be appreciated by those in the audience who are keeping notes of the discussion.

(9) If the subject matter under discussion is such that significant points or conclusions are developed, the chairman should summarize them in tabular or chart form on the blackboard. Such charts assist greatly in avoiding sidetracks or excursions into other unrelated topics to which a discussion frequently wanders. They tend to center the attention of the group and are of benefit to the chairman in helping him to concentrate.

(10) The chairman should make certain that those who talk do so in a manner that all present can hear.

(11) He should stick to the subject.

Engineers' Responsibility in Civic Affairs

(*Continued from page 522*)

schools taking part in this conference today, when discussing students' interest in religion with a small group of us, said: "What can you expect when religious leaders cannot agree among themselves. I have therefore neither interest nor faith in religion."

We are all baffled by differences in denominationalism, but because we may differ violently in politics is no reason why we should lose faith in or cease to struggle for our great concept of democracy. Fortunately, science and the things of the spirit are no longer looked upon as incompatible.

Let us remember that citizenship responsibility has its vital roots deep within the Christian fundamental, "Love thy neighbor as thyself."

Our material growth has been and continues to be rapid and far-reaching—our research laboratories pour forth advances in pure science, new devices, new processes. For the years of peace just ahead could we ever better afford to divert some of the precious time available to training engineers for direct responsibility of citizenship?

What value has all this material progress if by reason of neglect or indifference we train engineers who are unmindful of responsibilities of citizenship?

What doth it profit a nation if it gain the whole world and lose its own soul?

In conclusion, in view of the new postwar world which soon may be upon us, let us seriously consider broadening the base of engineering education. Let us help to build a sense of citizenship responsibility in our engineering students by a substantial and dignified core of study running through all four undergraduate years, and let us encourage men to believe that religious motivation is both a valued and respected element in good citizenship.

PATENTS, TECHNOLOGY, *and* FREE ENTERPRISE[1]

By ROBERT L. BISHOP

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

THE more imponderable are the arguments for and against a policy the more extreme are the opinions of the opponents. This has certainly been true of the controversy which has raged for the past five years about the effects of our patent system.

The storm center in the agitation for changes in our patent laws has been Thurman Arnold. As head of the Anti-Trust Division of the Department of Justice and as a member of the Temporary National Economic Committee, he figured prominently in that Committee's investigation of patents. Largely inspired by evidence introduced by the Department of Justice[2] and by Mr. Arnold's personal suggestions, the T.N.E.C. recommended, in its preliminary report, the abolition of restrictive licensing; and then, in its final report, it urged the broadest compulsory licensing at reasonable royalties. The T.N.E.C. monograph, "Patents and Free Enterprise," by Walton Hamilton of the Yale Law School, was another document strongly critical of the patent system.[3]

Some rebuttal was forthcoming even within the T.N.E.C. Commissioner Conway Coe of the Patent Office replied at length to Mr. Arnold's recommendations; and all the inventors, businessmen, and patent lawyers who appeared before the Committee left no doubt about their opposition to such measures.[4] The most extensive criticism was made in the book, "Patents and Industrial Progress," by George E. Folk, a patent lawyer and patent adviser to the National Association of Manufacturers.[5]

Both Mr. Arnold and his critics, like Lawrence Langner, have carried the controversy to the magazines. More recently Robert L. Wilson has written two articles in defense of the present system in the *Technology Review* for April and May; and the *Journal of Commerce* published a supplement in March, 1943, "The Public Interest in a Sound Patent System," containing short articles by an imposing array of authorities interested in patents.

Critics of substantial change in our patent laws, who may be called "the conservatives" for want of a better name, have many grounds for their complaint about the one-sidedness and, on occasion, the ignorance of the reformers. For example, Mr. Arnold deserved his critics' scorn for a remark that showed his failure to appreciate Dr. Thomas Midgely's research on ethyl gasoline: "Now whether these patents were good, I do not know. It struck me at the time, what else could you do with tetraethyl lead but put it in gasoline? You can't put it in coffee."

The proponents of compulsory licensing, with their eyes on the situations which would make that desirable, are frequently open to the criticism that they fail to give proper weight to the undesirable effects of such a reform. The power to put a more efficient competitor out of business would be limited; but compulsory licensing might also reduce competition where a small firm needs to exclude more powerful competitors from its inventions to survive. Again, the advocates of unrestricted licensing seem much too cavalier about the cases where no licensing will be the alternative to restricted licensing.

Another major criticism of both the T.N.E.C. and last summer's Senate Patents Committee is that they frequently fail to show the necessary connection between a recommended change of the patent law and the abuses to be cured. In the special case of Mr. Arnold, anti-trust enforcement and patent-law reform frequently get in each other's way. The glass-container industry was his principal exhibit of the need for patent reform. Then a District Court decision in an anti-trust case resoundingly convicted all the leading companies in that industry and threw all their patents open royalty-free. The defendants had unsuccessfully quoted Mr. Arnold of the T.N.E.C. about "perfectly legal" practices in their industry; and now his opponents on patent reform are all the stronger in their contention that his own vigorous anti-trust enforcement is all that patent situations need.

On the other hand, the reformers are certainly not alone in their failings. The conservatives, in their zeal to conserve what they rightly feel to be the great virtues of the patent system in encouraging technological progress, have frequently overstated those virtues or have given insufficient weight to the valid considerations that motivate the reformers. Many economists give considerable weight to these aspects, and it is hoped that a discussion of them here will prove profitable.

To be sure, the conservatives favor some changes. In general they approve the T.N.E.C. recommendations about procedure which derived from testimony presented by the Department of Commerce and which have already been enacted into law. Many conservatives, although not including the patent bar, also favor a Single Court of Patent Appeals, which would simplify patent litigation and concentrate it in a court especially fitted to adjudicate its technical issues; and many acknowledge the merit of the 20-year reform, which would put that limit on the period from patent application to expiration. But the considerations that inspire Mr. Arnold to abolish restrictive licensing or to institute compulsory licenses are lost on the conservatives. Their rebuttal would be strengthened if their one-sidedness did not rival Mr. Arnold's.

As an example of overstatement, consider this from Dr. Frank B. Jewett in the *Journal of Commerce* supplement: "Personally, during an experience in industry of nearly forty years I have never known of a single authenticated case where a valuable invention was willfully suppressed. Nor have I ever met anyone who claimed to know of a single such case." Dr. Jewett is perfectly correct in distinguishing suppression from nonuse where a patented process is unused because it is impractical or inferior to other processes that are used. But it is also quite clear that a company may have the incentive not to use or to delay the introduction of a superior process. This would merit the term "suppression." If a company has a large commitment in one process, a better process will have to cover the costs of obsoleting the old before it will be introduced. If the better process is available to a competing firm it will be introduced immediately; and that is the public interest.

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[1] One of a series of reviews of current economic literature affecting engineering, prepared by members of the Department of Economics and Social Science, Massachusetts Institute of Technology, at the request of the Management Division of The American Society of Mechanical Engineers. Opinions expressed are those of the reviewer.

[2] T.N.E.C. Hearings, Part 2, December, 1938, U. S. Government Printing Office, $0.75.

[3] "Patents and Free Enterprise," by Walton Hamilton, U. S. Government Printing Office, $0.25.

[4] T.N.E.C. Hearings, Part, 3, January, 1939, U. S. Government Printing Office, $0.35.

[5] George E. Folk, "Patents and Industrial Progress," Harper and Brothers, New York, N. Y. 1942, $3.

Lawrence Langner says in the same publication: "Americans are . . . more willing to destroy a satisfactory present in order to create a better future." It is also true that sometimes patents allow a company, in its own interest, to postpone the better future.

As another example, we know that the public utilities brought pressure to suppress fluorescent lighting until they became convinced that the public would use the more efficient lighting in sufficiently greater quantities to keep its consumption of electric power from declining. Where fluorescent patents or development are controlled by someone with a large stake in an inferior lighting or in electric power, it is perfectly apparent that their incentive to innovate or push research in the innovation may be that much weaker. Hence Dr. Jewett is wrong in some instances that "the purely selfish interests of individuals or corporations demand that they put significant patents to work as rapidly as possible."

It is practically impossible to assess the quantitative significance of patent suppression because no firm would advertise such a practice. Responsible engineers and patent lawyers have informally mentioned cases of it, but documented instances come out only in court cases or when a company's files are subpoenaed. The Supreme Court, as a matter of fact, has declared patent suppression to be legal in Continental Paper Bag Co. Vs. Eastern Paper Bag Co., where the plaintiff purchased patents covering machinery superior to his own "specifically for the purpose of suppressing the superior machines."

Patents provide an incentive to prevent technical progress by others at the same time that they encourage invention. In a subpoenaed company memorandum before the T.N.E.C., two of the three main purposes in taking out patents were stated to be: "(*b*) To block the development of machines which might be constructed by others for the same purpose as our machines, using alternative means . . . (*c*) To secure patents on possible improvements of competing machines, so as to 'fence in' those and prevent their reaching an improved stage." Of 200 applications filed by the company in 1927, 1928, and 1929, 112 were stated to be for these two purposes. Dr. Jewett would be more convincing if he confined himself to the argument that patent suppression is infrequent in occurrence and minor in importance. With that we might be able to agree.

Another point which the conservatives characteristically underestimate is that our large corporate organization of business has introduced implications into the working of our patent system which were not there when it was established in 1790. A company with a head start in an industry because of a basic patent may maintain its monopoly or, at least, its protection from severe competition by patenting improvements as rapidly as necessary. Walton Hamilton has been taken to task for speaking of this in terms of prolonging the life of the monoply or giving to a grant "a new lease on life." Now, Professor Hamilton is no doubt guilty of flamboyant forms of expression which understandably irritate his critics; but he also shows himself perfectly aware that patents expire in 17 years. His criticism is not met by stating that "no patentee can prolong the life of his patent by so much as a single day." The point is that monopoly of the industry is prolonged by new patents when production under the old patent, now obsolete, is no longer a legal monopoly. The monopoly may also be prolonged by the barriers to competition of large capital investment and unpatentable "know-how."

This presents a feature which public policy must consider. The patent system, as everyone admits, rests on a *quid pro quo*. If the *quid* of limited monopoly results in an effectively prolonged monopoly, the legislators do well to consider whether that has not become too high for the *quo* of invention and disclosure. To be sure, the monopolist benefits the public by the improvements which refresh his monopoly; but the public may not gain as quickly or as much as it would under modified arrangements.

Not only may monopoly of production be maintained but an effective monopoly of research and invention may prevent the generally recognized stimulus of competition in those activities. It is not sufficient to say that "In this matter of making and patenting improvements there is a field of perfectly free competition." Legally, this statement is perfectly correct; but it may be quite wrong as a matter of effective reality. On this score, the tables seem to be turned. The practical men are content with a legal theory not always borne out by the practice under their very noses.

The turnabout tale of theory and practice appears more than once in the patent controversy. Professor Hamilton is bitterly attacked by Mr. Folk and others for his characterization of the patent right as a privilege "staked out in the public domain." Of course, the critics are correct that the patent is, in theory, an addition to knowledge and not a subtraction from the previously known public domain; but in practice this is not always strictly true. It is no reflection on the integrity of the Patent Office to say that it is not always able, under its great pressure of work, to keep questionably valid patents from issuing with broad claims. Many such patents collapse in the courts against a strong adversary. Yet frequently such patents can be used to intimidate a financially weak competitor. One consequence of our present patent system is that it makes legalistic competition so important. It is responsible for an "economy" of large-scale business organization that may have no relation to economies of production or even research.

A patent of questionable validity, especially when backed by large financial resources, may also be the occasion of an agreement which would be in restraint of trade were it not for the patent connection. Companies may agree not to contest the validity of patents which could otherwise be upset, because a patent-regulated industry is more to their liking than the more competitive situation that would follow patent invalidation. This poses a dilemma. No one likes to see litigation multiplied. But litigation may advance the public interest by upsetting patents that do not deserve existence.

The dilemmas that appear so often in the patent controversy are usually a part of the basic dilemma of patents: legal monopolies of technology prevent our best use of present technology and are handicaps to our fabric of free enterprise; but, on the other hand, the monopoly bait is a strong inducement to an expanding technology, with which we may tamper at our peril.

N. E. Steels

METAL PROGRESS

IN pamphlet form, *Metal Progress* has republished, with some additional material, a number of articles on the National Emergency Steels. These steels were established as a means of conserving the scarce alloying elements. The alternate steels do not include the following types of steel: Low-alloy high-tensile steels which are furnished as flat-rolled products and which require no heat-treatment before use; stainless steels or irons such as the high-chromium or chromium-nickel types; medium-chromium (2 to 10 per cent chromium) steels which sometimes contain other elements and which are used to resist scaling at elevated temperatures; or any class of tool steel, carbon or alloy.

The 72-page pamphlet contains tables of physical and chemical properties and many charts, as well as results of tests on the new steels.

COMMENTS ON PAPERS

Including Letters From Readers on Miscellaneous Subjects

Analyzing Heat Flow in Cyclic Furnace Operation

Comment by G. M. Dusinberre[1]

The writer was much interested in the present paper[2] and believed the authors had overlooked something in not considering for the solution of their problem the numerical method outlined by Emmons.[3] The writer decided to try this method, keeping a careful check on time spent. The results were as follows:

	Experimental	Electrical	Numerical
Preparation...	2 days	20 hr	28 hr 10 min
Test (or computation)...	5 days	30 min	2 hr 35 min
Evaluation...	5 days	20 hr	1 hr
Total....	12 days	40 hr 30 min	31 hr 45 min

In fairness to the numerical method, even if in disparagement to the writer, it must be admitted that 6 hr of the preparation time were wasted in "pilot runs," based on handbook data which did not correspond to the actual refractory, and 3 hr were wasted in locating and correcting an error in algebra. Thus, in the hands of a better worker, we might credit the numerical method with only 22 hr 45 min.

Of course time itself is often the criterion for correct engineering procedure. But more often we have to think of cost. It would be interesting if the authors would quote man-hour figures and cost of equipment for the experimental and electrical methods. For the numerical method, the time is to be multiplied by unity to get man-hours, and the necessary equipment consists of a pencil and a slide rule.

The degree of accuracy attained may be judged from a table of the maxima and minima of curves 2 to 5 of the authors' Fig. 3, compared with the computed values. On the figure as published, temperatures could be read only to the nearest 10 to 20 deg and calculations were made only to the nearest 10 deg.

TABLE 1 DEGREE OF ACCURACY OF AUTHORS' CURVES, FIG. 3 OF PAPER

	Curve	Fig. 3	Computed	Error
1st max	2	1360	1430	70
	3	890	940	50
	4	540	540	0
	5	170	170	0
1st min	2	500	520	20
	3	430	420	10
	4	290	290	0
	5	130	130	0
2nd max	2	1470	1490	20
	3	1030	1000	30
	4	620	580	40
	5	180	180	0
2nd min	2	680	690	10
	3	560	540	20
	4	360	350	10
	5	140	140	0
3rd max	2	1480	1510	30
	3	1050	1020	30
	4	640	590	50
	5	180	180	0
3rd min	2	680	690	10
	3	550	540	10
	4	360	350	10
	5	140	140	0
4th max	2	1490	1510	20
	3	1060	1030	30
	4	650	600	50
	5	190	180	10
4th min	2	640	660	20
	3	530	550	20
	4	360	370	10
	5	140	150	10

It appears to the writer that the accuracy of the results is consistent with the accuracy of the data used and is comparable with the accuracy of the electrical method. Whether a particular degree of accuracy is "satisfactory" from an engineering standpoint depends upon the ultimate use to be made of the results. This question may well be left to the authors.

Dr. Paschkis has suggested in a personal communication that a fair comparison of methods should require computation of the four intermediate points which were represented on his electrical circuit but were not reported in the paper. If this information is essential and cannot be obtained accurately enough by interpolation, then we must multiply the computation time by about 7, giving an estimated time for the numerical method of 38 hr 15 min, and an equal number of man-hours. No more evaluation time is required since all work is done directly in terms of temperatures.

The method, and the simplicity of the calculations, can be seen from the example, Table 2, which is taken from the beginning of the fourth day.

TABLE 2 SAMPLE CALCULATIONS

Item	Column 1	2	3	4	5
A	9:30	10:28	11:24	12:18	1:10
1	72	160	195	195	195
B	6	14	17	17	17
1′	78	174	212	212	212
2	71	69[a]	100	122	132
3	58	56	54[a]	63	73
4	38	37	36	35[a]	37
5	15	15	14	14[a]	14[a]
C	8	8	8	7	7
5′	23	23	22	21	21

[a] These points are values for the third minimum on the respective curves.

Notes:

Item A. Time. The varying intervals allow for variation of mean diffusivity of the brick with mean temperature throughout the cycle.

Item 1. Temperature of hot surface picked off curve 1 of the authors' Fig. 3. The last figure is dropped, here and subsequently.

Item B. This is about the simplest, but still a rather effective, means of allowing for variation of diffusivity along the brick at a given time. It has the disadvantage of making the cold surface temperatures a little too high. The value of this item is 0.09 (T_1 —100), where T_1 is taken in the same column.

Item 1′. Sum of item 1 and item B.

Item 2. Arithmetical mean of items 1′, 2, and 3 in preceding column. This corresponds to curve 2 of Fig. 3.

Item 3. As given, from items 2, 3, and 4.

Item 4. As given, from items 3, 4, and 5.

Item 5′. From items 4 and 5 in preceding column, item 5 being given double weight. This would be the cold-surface temperature if there were no loss to surroundings.

Item C. This allows for radiation and convection to surroundings. In this calculation, a constant value of 0.63 (T_6' — 100) was used. T_5' is taken from the same column.

Item 5. Item 5′ minus item C, from same column. This is the computed surface temperature corresponding to curve 5 of Fig. 3.

As has been noted, the evaluation of results is simple since we work directly in temperatures throughout. The external heat loss may be estimated from curves 2 and 5, as in Table 3.

With the data at hand we can estimate the internal heat loss (to leakage air) from the total loss less external loss

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[1] Assistant Professor of Mechanical Engineering, Virginia Polytechnic Institute, Blacksburg, Va. Now on duty at U. S. Naval Academy, Annapolis, Md. Mem. A.S.M.E.

[2] "Analyzing Heat Flow in Cyclic Furnace Operation," by C. B. Bradley and C. E. Ernst, Mechanical Engineering, February, 1943, pp. 125–129.

[3] "The Numerical Solution of Heat-Conduction Problems," by H. A. Emmons; presented at the Annual Meeting, A.S.M.E., Nov. 30–Dec. 4, 1942.

TABLE 3 ESTIMATE OF EXTERNAL HEAT LOSS

Average temperature on curve 2, deg F	1076
Average temperature on curve 5, deg F	163
Mean temperature difference, deg F	913
Mean temperature, deg F	620
Conductivity at mean temperature, Btu per in. per sq ft per deg F per hr	1.05
Distance between points 2 and 5, in.	6.75
Heat loss $\frac{913 \times 1.05 \times 24}{6.75}$, Btu per sq ft, per deg	3410

during the 16-hr cooling period. This comes to about 500 Btu per sq ft, but the figure cannot be considered very precise since it is the difference of two large numbers.

As a minor criticism of this interesting paper, it is suggested that the actual thermal characteristics of the brick should have been published. The authors kindly furnished the writer this information very promptly on request. It is also suggested that the time coordinates of Fig. 3 should have been chosen commensurate with the cycle.

In conclusion, the writer views the matter about as follows:

1 The numerical method offers a saving of time and of man-hours in this and in many similar cases.

2 The numerical method may become unduly lengthy if a large number of cases must be solved, or if a high degree of precision is justifiably demanded. The calculations may become unduly cumbersome in two or three dimensions. In these cases the remarkably ingenious apparatus of Dr. Paschkis would have the advantage.

3 The numerical method requires a minimum of equipment. The writer used a pocket adding machine for some of his "pilot runs," but this was for carrying temperatures to the nearest degree, a fictitious accuracy not warranted by the data. Only a pencil and slide rule were used in the work reported here.

4 The numerical method can be used by any engineer who will study the Emmons paper[3] and use some effort in adapting the calculations to the particular physical situation in hand.

APPENDIX TO DUSINBERRE COMMENT

The basic equation used is, in Emmons' notation,[3] as follows

$$\delta_t = \delta_x^2/2\alpha$$

This may be interpreted as follows: (1) With a material having diffusivity α; (2) using an averaging procedure, defined by the numerical constant (2, in this case); (3) we find a temperature which exists at a point in space defined by δ_x; (4) and at a point in time defined by δ_t.

We start by taking δ_x as $2^1/_4$ in., the spacing of the authors' thermocouples. Instead of 2 we use 3 as the numerical constant. This results in the foregoing averaging procedure and was done merely for the sake of getting a δ_t comparable with the intervals used by the authors, without changing δ_x.

Taking the mean diffusivity against time, we find that δ_t should range from 50 to 58 min throughout the cycle.

This simple procedure does not give good enough results in this case, owing to the large variation of diffusivity with temperature in this material. Confining our attention to what happens in any given time interval, if there is a variation of α across the brick, then δ_x must vary as $\sqrt{\alpha}$, if δ_t is fixed; that is, the computed temperatures, at the end of the interval δ_t, do not exist at the points defined by the originally chosen δ_x, but at points closer to the cold side of the brick. Then the temperatures at the chosen points are somewhat higher than the computed values. Plotting a few cases with δ_x proportional to $\sqrt{\alpha}$, we find that the computed temperatures should be increased 7 to 10 per cent, averaging about 9 per cent. This correction strictly should be applied after completing the calculations but, in the present case it can be done with a fair degree of accuracy simply by using a fictitious surface temperature 9 per cent high. If the cooling period were relatively longer we should have to shade this percentage of 9.

For the surface, an average h for radiation plus convection was used. The value was 2.4 Btu per sq ft per deg F per hr. We write the approximation

$$q = h\delta_t t = c\rho\delta_x (t' - t)$$

where t' is a fictitious surface temperature which would have been reached if the surface were insulated. This t' also enters into other relations which might have been used, e.g., Equation [4] of the Emmons paper.[3] The foregoing relation leads to the computation procedure used and has the advantage of being convergent.

COMMENT BY E. S. DAVIS[4]

The problem expounded in this paper transcends the mere analysis of a particular furnace operation; in fact it brings to the fore the whole question of the most economical method of analysis available to the engineer for the solution of any particular problem.

Before considering this more general question, it would be well to discuss the actual work done by the authors and also the analyzer developed by Dr. V. Paschkis at Columbia University.

The Paschkis analyzer is but one of many types of analyzers either suggested or developed in the past decade. It is noteworthy, however, because of the high degree of refinement which it has reached through the efforts of Dr. Paschkis and because of the excellent results which it gives in many actual cases. As has been already pointed out, the analyzer, which is an electrical instrument, may be used to solve problems of heat or mass flow in either the steady or unsteady state. Suffice it to say that the results obtained are in good agreement with experimental data as may be seen for the case in Fig. 3 of the paper.

Moore of Michigan has developed an instrument known as the hydrocal, which is intended for the solution of similar problems by means of a hydrodynamic analogy. Unfortunately, the writer is not aware how well developed this instrument is, or in how close agreement the results given by it are with the experimental data available for problems which it may solve. Any type of physical analogy may be developed for the solution of various problems whether electrical, hydraulic, or mechanical.

The direct experimental method of problem solution is supposedly the most accurate if the experimenter is able to set up a model which is commensurate with the actual problem, and if he is then capable of making the proper measurements. This, unfortunately, involves the intrinsic limitations of time and expense. Oftentimes, it is virtually impossible to set up actual physical models to determine the solution of every problem which may arise in actual engineering practice.

The third basic method of solution is the mathematical attack. This supposedly would be the most rapid and least expensive, but for the fact that our mathematical knowledge is still limited, especially in its engineering applications. Even to this day, the engineering courses of most universities do not require more than two years of mathematics, which means that our limited mathematical knowledge is not in general available to very many engineers. This is indeed an unfortunate situation which warrants an immediate remedy.

Let us look at the particular problem involved in this paper. The Paschkis analyzer was capable of providing a complete solution in less than two days, using only equipment at hand. The direct experimental method required 12 days, and the use of much material and equipment, which probably would not be at hand originally. Fig. 3 of the paper shows that the results obtained by the two methods are equally good in obtaining the desired solution.

The following is an outline of how the mathematical attack would proceed: For unidirectional heat flow in the unsteady state, the basic differential equation is

$$\frac{\partial u}{\partial t} = \alpha \frac{\partial^2 u}{\partial x^2}$$

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[4] American Locomotive Company, Alco Products Division, New York, N. Y. Deceased.

the general solution of which, after applying the boundary conditions, would be

$$u = u_h + \sum_{m=1}^{\infty} C_m e^{-\alpha^2 b^2{}_m t} \sin b_m x$$

where

$$C_m = \frac{2(b_m{}^2 + h^2)}{b_m{}^2 c + h(hc + 1)} \int_0^c [f(x) - u_h] \sin b_m x dx$$

and b_m are roots of

$$b \cos bc + h \sin bc = 0$$

where

u_h = temperature at inner surface
$f(x)$ = initial temperature distribution
h = transfer rate at outer surface
All temperatures relative to 100 F

This would proceed through the first cycle until the heat was shut off when the distribution given by the foregoing solution would be used as the initial distribution to apply in the basic differential equation for the second half cycle. This process would be repeated for as many cycles as were desired. The work entailed in solving for the coefficients of the Fourier series involved, and the actual evaluation would probably require 4 or 5 days. This indicates that, from an engineering point of view, if many problems require solution, then it would be definitely worth while to make up a set of curves based on the general solution. If but a single solution were required, then the analyzer could profitably be used.

It should be noted that the mathematical attack indicated is not the only one possible. Emmons of Harvard has recently shown how Southwell's relaxation method may be applied to engineering problems of heat flow. This method also gives comparatively rapid results, and, although the writer has not tried to use it for solving this problem, others have succeeded in getting results rapidly by this means.

Somewhat similar to the Emmons method is the discontinuous-step process of Hrones, which unfortunately has not been developed as yet to the high degree of applicability of some of the other methods available.

It is true that both the analyzer and mathematical attacks require a knowledge of the physical properties of the materials involved. However, our engineering knowledge in this field is fortunately increasing and the degree of uncertainty is probably equivalent to the uncertainty involved in the actual physical measurements made on real models.

Today, the engineer must be an economist as well as a technologist. He must be able to balance the relative costs involved in any particular process or design. To take the case in hand, as the authors have pointed out, the economical thickness of insulation for a given case is obtained by balancing the saving in fuel costs against the increase in insulation costs with thickness. In the paper, we see how the temperature distribution is obtained over a large number of cycles. Using the mean-temperature difference thus obtained in the thickness equation already presented, the economic thickness is readily found. In the past, there have been cases where engineers have disregarded this economic balance and merely calculated insulation thicknesses required to cut heat losses by a given percentage regardless of expense involved.

The temperature gradient across a wall composed of many layers of bricks may show discontinuities at the junctions despite proper cementing. The writer has actually conducted such experiments and has seen this occur. Such boundary resistances can only be estimated on the analyzer or in mathematical solutions, which is another inherent weakness in such solutions. Fig. 1 of this discussion shows possible temperature discontinuity through a wall.

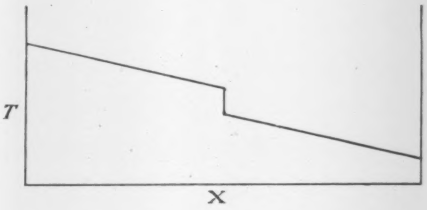

FIG. 1 POSSIBLE TEMPERATURE DISCONTINUITY THROUGH WALL

There are certain types of problems where direct measurements are extremely difficult and where even Dr. Paschkis' apparatus may not be useful in obtaining a solution. Then, the mathematical attack will be the only one available for engineering purposes. An example of this came to the writer's attention a few months ago. It was desired to determine the temperature distribution across a longitudinal fin over which heavy oils were flowing. The solution is extremely simple, if a uniform transfer coefficient may be assumed across the fin. Unfortunately, this is nowhere true; hence it was necessary to derive a mathematical function to express this variation. Once this was done a mathematical solution was obtained and the average temperature of the fin could be obtained by integration.

Before this mathematical attack was attempted, Dr. Paschkis had been consulted and he encountered the same difficulty which made it impossible properly to employ his analyzer for the solution of this problem.

This incident is cited merely to show that there is no universally applicable method to solve all problems. In engineering work, the engineer must use judgment and foresight to estimate properly the intrinsic difficulties involved in solving a particular problem, and, having adequately weighed these, he must decide which is the most practical method of attack. This is essentially the greater problem lying behind the immediate one analyzed so well by the authors.

Comment by V. Paschkis[5]

The writer has read with interest the discussions by G. M. Dusinberre and E. S. Davis.

Both discussers suggest some mathematical means for solving the problem which the authors have approached by direct experiment and the writer by using the heat-and-mass-flow analyzer.

Undoubtedly there is no one method which is best fitted for all problems, and the choice between the different approaches depends upon the nature of the problem. The analysis of the Bradley-Ernst problems was carried out on the analyzer more as a proof of the validity of the method than as a means in itself.

Mr. Dusinberre stresses the comparison of the time estimate of 40 hr 30 min used on the analyzer with 31 hr 45 min on one basis, or 38 hr 15 min on another. The 40 hr 30 min, however, included the actual drawing of graphs, which is not included in the time for the numerical method.

The main advantages, however, are not to be seen in a few per cent more or less time but in the flexibility of the analyzer method, which will be discussed.

Both discussers question the economic soundness of the analyzer approach because of the cost of equipment. This argument would be justified for those considering creating a new analyzer, but fortunately this is not necessary.

The analyzer used in connection with the present paper is in well-developed form and is directly available for a wide variety of technological problems coming up in industry. The speed of the actual measurement makes it possible to solve a great number of problems in a limited time on this one piece of equipment.

Mr. Davis mentions the setting up of curves from which solutions can be easily read. Such families of curves can readily be made up on the analyzer—in fact, much faster on the analyzer than by computation in tabular form.

This is due to the extreme flexibility of the electrical method. Once the circuit has been calculated and is set up, a change in a thermal property (film conductance, thermal conductivity, etc.) can be obtained in a few minutes, just by changing the position of a few switches. This easy way of adjustment is considered as one of the major advantages of the method. It affords a quick survey of the relative influence of different variables.

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[5] Research Associate in Mechanical Engineering, Columbia University, New York.

Mr. Davis mentions discontinuity in walls due to joints. The writer doubts if a temperature drop, as in Fig. 1 of his comment, is ever obtained. True, the mortar joint may have a very different conductivity from the brick; or the mortar may have crumbled away so that brick faces brick. In either case, the inclined line of temperature in the brick will be interrupted. However, the drop in temperature (due to the joint) would take place over a finite length (x), and not, as Mr. David shows, over an infinitely small length x.

Such irregularities, while offering major difficulties to the mathematical approach, could be solved easily enough on the analyzer.

Referring to Mr. Davis' comment on the first problem, there are always special cases where a mathematical solution may answer the particular purpose at the moment, as an alternate solution by means of the analyzer.

AUTHORS' CLOSURE

The properties of the insulating refractory brick used in the test wall are as follows:

Density = 31 lb per cu ft
Specific heat = 0.23 Btu per lb per deg F
Thermal conductivity at the following mean temperatures:

Mean temperature, F	400	600	800	1000	1200
Thermal conductivity..	0.99	1.04	1.11	1.19	1.29
Mean temperature, F	1400	1600	1800	2000	..
Thermal conductivity..	1.42	1.56	1.73	1.91	..

In addition to the results reported in the paper, it is of interest to note that the calculated heat flow for the steady-state condition is 5496 Btu per sq ft for 24 hr, which compares with the unsteady-state heat flow for the equilibrium cycle of 3350 Btu in the direct test and 3486 Btu, as measured with the analyzer.

Inasmuch as the interesting discussions of Commander Dusinberre and Mr. Davis were concerned almost exclusively with the relative merits of the numerical methods and the heat-and-mass-flow analyzer, the authors feel that Dr. Paschkis is much better qualified to reply to them than they are. Therefore, they can do little more than to concur in Dr. Paschkis' comments.

Anything which promotes examination and discussion of the various methods of solving unsteady-state heat-flow problems is worth while, and, in so far as this paper has accomplished such a purpose, the authors feel that their efforts have not been in vain.

A.S.M.E. BOILER CODE

THE Boiler Code Committee meets monthly for the purpose of considering communications relative to the Boiler Code. Anyone desiring information on the application of the Code is requested to communicate with Committee Secretary, 29 West 39th St., New York, N. Y.

The procedure of the Committee in handling the cases is as follows: All inquiries must be in written form before they are accepted for consideration. Copies are then sent by the Secretary of Boiler Code Committee to all of its members. The interpretation, in the form of a reply, is prepared by the Committee and is passed upon at a regular meeting.

This interpretation is later submitted to the Council of The American Society of Mechanical Engineers for approval and then issued to the inquirer and published in MECHANICAL ENGINEERING.

Following is a record of the interpretation at the meeting of April 30, 1943.

CASE No. 958 (Reopened)

(Interpretation of Specification S-18)

Inquiry: The Code states that welded open-hearth and seamless steel tubes, Grades *A* and *B*, complying with A.S.T.M. Specifications A106-41 will be acceptable as complying with Specification S-18. Will pipe complying with A.S.T.M. Specifications A106-42T be acceptable as complying with Specification S-18?

Reply: It is the opinion of the Committee that welded open-hearth and seamless pipe made from open-hearth or electric-furnace steel, complying with A.S.T.M. Specifications A106-42T, will be acceptable as complying with Specification S-18.

CASE No. 981 (Reopened)

(Special Ruling)

Inquiry: Is it permissible to use the following A.S.T.M. Emergency Alternate Provisions affecting existing Code specifications: EA-A27(S-11), EA-A83(S-17), EA-A135(S-58), EA-A178(S-32), EA-A192(S-40), EA-A194(S-51), EA-A209 (S-48), EA-A213(S-52), EA-A216(S-56), EA-A217(S-57), EA-A240(S-62), EA-A249(S-64), EA-A250(S-65), EA-B12 (S-21), EA-B62(S-46), EA-B111(S-47)?

Reply: It is the opinion of the Committee that the above-mentioned A.S.T.M. Emergency Alternate Provisions for the corresponding Code specifications may be considered as meeting the intent of the Code.

CASE No. 985 (Reopened)

(Special Ruling)

Inquiry: In view of the difficulty in securing forged or cast butt welding and slip-on flanges and nozzles, will it be permissible to use flanges or necks fabricated by welding in the construction of boilers, piping, and unfired pressure vessels?

Reply: It is the opinion of the Committee that it is permissible to build up flanges or necks by fusion welding for use in the construction of boilers, piping, and unfired pressure vessels, provided:

(1) The manufacturer satisfies himself and the inspector by calculations (direct or comparative), or reference to the rules for bolted flanged connections, Pars. UA-18 to UA-24, inclusive), that the built-up welded flanges are equivalent in strength to the one-piece forged or cast flanges which they replace;

(2) The welds are made in general accordance with the details shown in Figs. UA-2 and UA-3 subject to the limitations of items (3) and (5). Hub reinforcements may be provided by additional welding at the back of the flange or by reinforcing plates suitably attached. Details of construction not shown on these figures are subject to the approval of the inspector;

NOTE: The welding details of Figs. UA-2 and UA-3 may be employed, as herein provided for, without conflicting with the intent of Par. P-112(*c*).

(3) For boilers and boiler piping applications, the details in Figs. UA-2(6), (7), and UA-3(10), (11) are limited to 16 in. nominal pipe size or $1^{5}/_{8}$ in. required wall thickness for parts to contain steam, and to 10 in. nominal pipe size or $1^{1}/_{8}$ in. required wall thickness for parts to contain water [which are the size limitations specified in Par. P-112(*a*)(1)], unless the welds are radiographed or examined by the magnetic powder method to prove the soundness of the weld;

(4) Facing and drilling of flanges for boilers and boiler piping conforms to the American Standard. (It is recommended that compliance with American Standard be made where practicable for all flanges used on unfired pressure vessels.)

(5) The details shown in Figs UA-2(6), (7), and UA-3(11*a*) are limited for boiler and boiler piping applications to 300-lb American Standard series and rating;

(6) The flanges are made of material recognized as weldable by the Code, except that hub type flanges shall not be machine-cut from plate material;

(7) All flanges to Fig. UA-3(10), (11) are stress-relieved. Flanges to Fig. UA-2(6), (7) are to be stress-relieved where the thickness of the neck, pipe, or shell to which they are attached is required to be stress-relieved by the provisions of Pars. U-76 or P-112.

A.S.M.E. NEWS

And Notes on Other Engineering Activities

Special Research Committee of A.S.M.E. Improves Forging of Steel Shells

When the first impact of the present war was felt in industrial plants getting into production of war material—some months ahead of our actual participation—it became obvious that our background in the manufacture of such ordnance items as high-explosive shells, etc. was not only remote, but information was meager and superficial.

Accordingly, discussions were had first within The American Society of Mechanical Engineers and later with U. S. Army Ordnance officers as to the best methods for putting this art on a firm scientific and engineering basis. A certain amount of peacetime work in government arsenals had resulted in some modifications, one important advance over World War I practice being the production of forge-finished cavities. However, the relative merits of the various possible forging methods, of billet separation, heating, descaling, shell drawing or elongating, nosing, etc., as well as practice improvements, production step ups, machinery specifications, shell-steel specifications, material conservation, etc., were yet to be studied and realized. A program involving tens of millions of vital war items is certainly a challenge to our best engineering and production ingenuity.

Suggested Program

As a result of these discussions, the shell-producing industry was canvassed as to its reaction to an Ordnance Department-backed shell-research program, which might:

(1) Build and operate on a commercial basis a pilot shell plant that would directly compare and evaluate all methods of shell making, various tool designs, tool materials, billet forms, deformation forces, etc.

(2) Conduct field studies, supported by laboratory research and theoretical studies, coupled with a real collation of operating data on production, tool life, production costs, defects, rejects, etc.

(3) Act as an active information exchange between all shell forgers in the United States and Canada, in which not front-office reports but real operating details, improvements, etc. are continuously made available to all properly approved personnel.

Because of the time that would be necessary to carry out the first suggestion, and the "lateness of the hour," it was the majority opinion that the first suggestion (pilot plant) should not be undertaken, at least at this time. The second and third suggestions were generally and heartily endorsed, however. Accordingly, in the summer of 1941, a meeting was held with Brig. Gen. G. M. Barnes, then Assistant Chief of Industrial Service, Office of Chief of Ordnance, who approved the eventual financial activation of a properly constituted A.S.M.E. committee, and the program of such a committee was outlined.

The committee is made up of men chosen for their breadth of experience in the various techniques and methods, as well as specialists in the theory of flow of metals, metal heating, tool metallurgy, etc.—rather than general representatives of each individual shell forger. Members from Canada were included, as they were able to aid materially by virtue of their earlier involvement in the war. Advisory members from the U. S. Army Ordnance Department and the U. S. Navy Bureau of Ordnance completed the scheme of the panel.

This committee prepared a work program, which, after being approved by the Ordnance Department, formally started its activities in June, 1942, with the opening of a field office in Pittsburgh. Later, subcontracts were let to the Case School of Applied Science in Cleveland for theoretical and experimental studies of shell drawing and to the Westinghouse Research Laboratories in East Pittsburgh for similar studies on shell nosing.

The committee has met monthly to direct and digest continuously the work in hand. All shell forgers, at their discretion, have appointed associated members to act in a liaison capacity with the committee's field representatives and to receive communications on the findings of the committee. The committee is now issuing its second preliminary report, and its final report will be completed in September.

Detailed Studies in 46 Plants

The work of the committee to date has demonstrated the feasibility and practical utility and workability of such an activity. Committee representatives have visited and conducted detailed studies in some 46 plants to date, spending from three days to two weeks, or more, in each plant, depending upon the individual case. In general, co-operation has been splendid, and increasingly so as the work progressed and the effectiveness of this type of activity began to evaluate itself. Detailed data have been secured on all the various phases of shell forging, billet separation, heating, descaling, forging proper, cooling, hospitalization (salvage of slightly defective forgings), etc. Data have also been secured on tool life, production, process economies, forces in forgings, drawing, nosing, flow of metal, etc., and in all cases from examination of shop records and shop observations, and not from transmitted secondhand impressions.

The work of the committee is so well known among shell forgers that the field men find a most cordial reception everywhere.

It is the aim of the committee to end up with the comprehensive treatise on shell forging, based on assembled data and studies, which will form the factual basis for the best national decisions in another emergency—should it ever arise. It cannot help but contain a set of considered conclusions and recommendations that would enable a more rapid and rational plunge into another war-production program, as well as influence the development or modification of our present program.

The Committee

The Committee consists of Dr. M. D. Stone, United Engineering and Foundry Company, Pittsburgh, Pa., chairman; J. J. Dierbeck, International Harvester Company, Chicago, Ill.; D. W. Fletcher, National Tube Company, Pittsburgh, Pa.; W. M. Frame, the National Supply Co., Ambridge, Pa.; W. N. Howley, Lansdowne Steel and Iron Co., Gadsden, Alabama; A. F. Macconochie, University of Virginia, University, Va.; W. P. Muir, Do-

A.S.M.E. Officers Are Nominated for the Coming Year

Nominations of 1944 officers of The American Society of Mechanical Engineers have been announced by B. P. Graves, Chairman of the National Nominating Committee which has been holding sessions at the Bismarck Hotel, Chicago, Ill. Election will be held by letter ballot of the entire membership of 18,000 closing on Tuesday, September 28, 1943.

The nominees as presented by the Committee are:

Office	Nominee
President	Robert M. Gates
Vice-Presidents	David W. R. Morgan Jonathan A. Noyes Ford L. Wilkinson, Jr. Rudolph F. Gagg
Managers	James M. Robert Samuel H. Graf Alton C. Chick

Biographical sketches of the candidates for office will be published in the August issue of Mechanical Engineering.

minion Engineering Co., Ltd., Montreal, Canada; A. Nadai, Westinghouse Electric and Manufacturing Co., East Pittsburgh; A. R. Nettenstrom, American Forge Division, American Brake Shoe and Foundry Co., Chicago; George Sachs, Case School of Applied Science, Cleveland; W. Trinks, Carnegie Institute of Technology, Pittsburgh; and A. E. Van Cleve, Crucible Steel Co. of America, Harrison, N. J. Advisory Members: U. S. Army Ordnance Department, Brig. Gen. G. M. Barnes and assistants and Brig. Gen. R. Hardy and assistants; U. S. Navy Bureau of Ordnance, Lieut. Com. A. H. Bateman; Department of Munitions and Supply, Ottawa, Ontario, Canada, C. D. Howe and assistants.

S. W. Dudley and B. F. Wood Honored by Clarkson College

At Clarkson College of Technology on May 10, S. W. Dudley, former member of the Council, A.S.M.E., and dean, School of Engineering, Yale University, was presented for the degree of Doctor of Engineering by L. K. Sillcox, member A.S.M.E. and member of the board of trustees of the college. Mr. Sillcox characterized Dean Dudley as "a true gentlemen—a great man—and a great friend of the truest aims that genuine education stands for, who has rendered professional services that will never cease to be remembered."

Benjamin F. Wood, member A.S.M.E. and vice-president, Stevens and Wood, Inc., New York, N. Y., was presented for the degree of Doctor of Engineering by Dr. Charles A. Pohl, alumnus and member of the board of trustees of the college. In presenting Mr. Wood for the degree Dr. Pohl said, in part, "During a ten-year period he built more than one hundred million dollar's worth of engineering work. His work has always been of the best. The Deepwater steam station on the Delaware River has consistently produced 90 per cent of its maximum output since construction. He is a man who inspires confidence both personal and professional. Money or engineering projects placed in his hands are a sacred trust."

Western Society of Engineers Elects Officers

C. Earl Webb, designer of bridges and western division engineer of the American Bridge Company, Chicago, has been elected President of the Western Society of Engineers for the year 1943–1944.

Philip R. Elfstrom, assistant chief engineer of the Chicago, North Shore, and Milwaukee and the Chicago, Aurora, and Elgin Railroads, becomes first vice-president; Henry T. Heald, member A.S.M.E., president of the Illinois Institute of Technology, becomes second vice-president, and T. G. LeClair, supervising development engineer of the Commonwealth Edison Company, was re-elected treasurer. New members of the board of direction are Paul Hansen, partner of Greeley & Hansen, sanitary consulting engineers, and H. C. Townsend, superintendent in charge of telephone-equipment manufacturing, Western Electric Company, both with headquarters in Chicago.

Actions of A.S.M.E. Executive Committee

At Meeting in Society Headquarters on May 28

A meeting of the Executive Committee of the Council of The American Society of Mechanical Engineers was held in the rooms of the Society on May 28, 1943, with President Harold V. Coes presiding. In addition to Mr. Coes there were present: George E. Hulse and Clair B. Peck, of the committee; G. L. Knight (Finance); W. A. Carter (Professional Divisions); A. R. Mumford (Local Sections); C. E. Davies, secretary; and Ernest Hartford, executive assistant secretary. S. H. Libby (Admissions) and Alfred Iddles (Society Office Administration) were present during the morning session.

The following actions were of general interest:

It was voted to postpone during the period of the war the annual Pi Tau Sigma Gold Medal award.

Authority was given the Secretary to proceed with the republication of the Biography on the Cutting of Metals, parts 1 and 2, and the publication of part 3 in one volume and in the format of the "Manual on Cutting of Metals," so that they may be considered as companion volumes.

Meeting Dates Approved

Upon recommendation of the Committee on Meetings and Program, approval was voted of the following Society meetings:

1943 Fall Canadian Meeting, jointly with The Engineering Institute of Canada (Sept. 30 and Oct. 1).

1944 Spring Meeting, Birmingham, Ala., during the week of April 3.

1944 Semi-Annual Meeting, Pittsburgh, Pa., during the week of June 19.

Appointments and Assignments

Approval was voted of the following personnel of the Manufacturing Engineering Committee: L. C. Morrow, chairman; Erik Oberg, vice-chairman; Harold V. Coes, Fred H. Colvin, and James L. Walsh.

The following assignments of members of the Council to Group Conferences were made: Group I, Providence, A. R. Stevenson, Jr.; Group II, New York, Clarke Freeman; Group III, Ithaca, Clair B. Peck; Group IV, Atlanta, W. R. Woolrich; Group V, Cincinnati, Jos. W. Eshelman; Group VI, Chicago, Albert E. White; Group VII, Seattle, H. L. Eggleston; Group VIII, Dallas, Guy T. Shoemaker.

Other Actions

The President was authorized to approve a contract with the War Production Board, continuing Production Clinics after July 1, 1943.

The gift by Mrs. James C. Sheers of a portrait of George Westinghouse was noted.

The Committee noted with regret the death, on December 25, 1942, and March 6, 1943, respectively, of Aurel Stodola, honorary member, and Percival Roberts, Jr., vice-president of the Society, 1893–1895.

It was voted to extend the congratulations of the Society to the Society for the Promotion of Engineering Education on the occasion of its Fiftieth Anniversary, to be celebrated at Chicago, Ill., June 18–20, 1943.

Commercial Standard on Mineral-Wool Cold-Storage Insulation

The National Bureau of Standards, U. S. Department of Commerce, in co-operation with the Industrial Mineral Wool Institute, has published in booklet form "Commercial Standard CS105-43, Mineral Wool; Loose, Granulated or Felted Form, in Low-Temperature Installations."

The standard covers both cold-storage area and pipe-line mineral-wool insulation. Based on research by engineers comprising the Institute's Specifications Committee, it also includes recommendations by engineers of the refrigeration field generally. Gratification that the Standard is established was manifest by 243 letters of acceptance from mineral-wool manufacturers, refrigerating engineers, cold-storage warehouses, food packers, U. S. Government agencies, and others signifying acceptance of the specification as their standard of practice.

Department of Labor Issues Safety Pamphlet

A pamphlet addressed to safety supervisors has been issued by the Division of Labor Standards, U. S. Department of Labor.

This pamphlet, called "Safety Speeds Production," contains material gleaned from the experience of hundreds of foremen which has been checked for accuracy and usefulness by safety engineers in large war plants acting as representatives of the Labor Department's National Committee for the Conservation of Manpower in War Industries

Requests for copies of the pamphlet should be addressed to the Division of Labor Standards, U. S. Department of Labor, Washington, D. C.

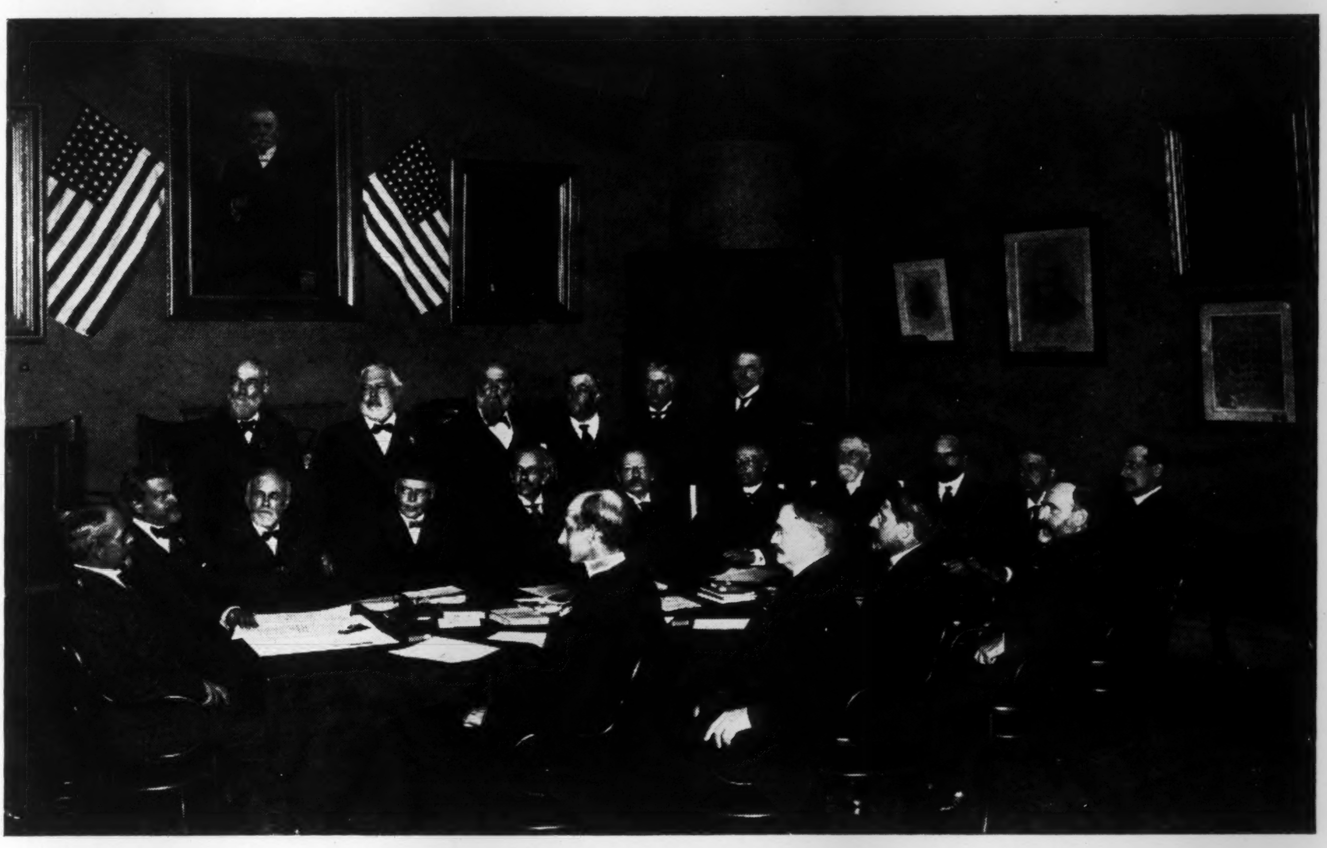
Joint Meeting of E.I.C. and A.S.M.E.

Toronto, Canada, Sept. 30 and Oct. 1

Plans are being perfected for a joint meeting, to be held at the Royal York Hotel, Toronto, Canada, September 30 and October 1, 1943, of The Engineering Institute of Canada and The American Society of Mechanical Engineers.

The secretaries and committees of the two Societies are working on a program of broad general interest along a pattern which will provide for the treatment of each topic selected by a Canadian engineer and one from the United States of America so that the experiences of both countries will be adequately presented.

Further announcement of topics and speakers will be made in MECHANICAL ENGINEERING as plans mature.



ILLUSTRIOUS A.S.M.E. MEMBERS AT COUNCIL MEETING IN 1903

(*Left to right, standing:* E. D. Leavitt, president and honorary member, A.S.M.E.; Charles Wallace Hunt, president; Geo. W. Melville, president and honorary member; Samuel T. Wellman, president; Wm. H. Wiley, treasurer of the Society for thirty-one years, 1894–1925; Milton P. Higgins. *Seated around the table, left to right:* James M. Dodge, president; Frederick R. Hutton, secretary, 1883–1906, and president; John E. Sweet, honorary member in perpetuity, a founder of the Society, and president; Henry R. Towne, honorary member and president; Oberlin Smith, president; Chas. H. Loring, president; Charles E. Billings, president; John Fritz, honorary member and president; Worcester R. Warner, honorary member and president; Chas. H. Corbett, Samuel S. Webber, James Christie, W. F. M. Goss, president; Robert C. McKinney; D. S. Jacobus, honorary member and president.)

A.S.M.E. Council Meeting Held Long Ago

THIS photograph was taken in 1903 during the presidency of James M. Dodge. It includes so many prominent men who have meant so much to the engineering profession that Dean A. A. Potter, past-president, A.S.M.E., sent it in to the Society archives. In his letter Dean Potter says, "Mrs. F. S. Cannon, the daughter of my illustrious predecessor, Dr. W. F. M. Goss, brought to me a number of treasures which belonged to her father and which I am depositing in the Goss Library of Engineering History. Among the material there was a photograph of a Council meeting which was held when James M. Dodge was president and Frederick R. Hutton was secretary. . . . . . Mrs. Cannon has given me permission to send you this photograph for such use as you may wish to make of it."

Dr. D. S. Jacobus, the only person of the group in the photograph still alive, recalls that it "was taken at a meeting of the Council at which a new constitution was adopted for the Society. The old constitution made all past-presidents members of the Council whereas the new one limited the number to the five surviving past-presidents who last held office. There were eleven past-presidents at the meeting whose terms of office had expired for more than five years. Someone proposed that as there were many of the old timers together as members of the Council for the last time that it would be fine to have a photograph taken as a souvenir of the occasion."

Proceedings of Water Conference of Engineers' Society of Western Pennsylvania

THE proceedings of the third annual water conference of November 9, 1942, of the Engineers' Society of Western Pennsylvania are now ready for distribution. Copies may be obtained by writing to the Society at the William Penn Hotel, Pittsburgh, Pa. The cost is $3 per copy, plus postage.

The contents of the proceedings cover the morning and afternoon sessions in complete form as follows:

Morning Session

At the morning session Dr. J. C. Warner, professor of chemistry, Carnegie Institute of Technology, Pittsburgh, Pa., presided as session chairman. The first paper presented was on "The Use of Inhibitors for Aluminum Chemical Equipment," by R. B. Mears and G. G. Eldredge, metallurgical division, Aluminum Research Laboratories, New Kensington, Pa. The second paper at this session dealt with "Recent Developments in Underwater Paints and Coatings," by F. N. Speller, metallurgical consultant, Pittsburgh, Pa.

Afternoon Session

At the afternoon session Dr. D. S. McKinney, assistant professor of chemistry, Carnegie Institute of Technology, Pittsburgh, Pa. was presiding chairman. Frederick G. Straub, research professor of chemical engineering, University of Illinois, presented a paper on "Solubility of Salts in Steam at High Pressures." The second subject was "Protection Against Caustic Embrittlement by Coordinated Phosphate pH control," given by S. F. Whirl, chief chemist, and T. E. Purcell, Mem. A.S.M.E., general superintendent of power stations, Duquesne Light Company, Pittsburgh, Pa.

Papers, discussions, and comments from the floor are incorporated in the proceedings.

James L. Walsh Appointed by Chief of Ordnance to Safety Council

JAMES L. WALSH, chairman of the A.S.M.E. War Production Committee, has been appointed by Major-General Levin H. Campbell, Jr., Chief of Ordnance, as a member of the Safety Council of the Chief of Ordnance, U. S. Army.

The Safety Council advises the Chief of Ordnance on matters relating to the safety programs in the manufacture, loading, and transportation of explosives. It is composed of persons connected with the explosives and transportation industry, and public health and safety officials, including the Bureau of Mines.

The chairman of the Safety Council is W. S. Carpenter, president, E. I. du Pont de Nemours, and Company, and the vice-chairman is E. B. Yancey, general manager of the same company.

Smoke-Abatement Rules, Hudson County, N. J., Revised

THE Department of Smoke Regulation, Board of Health and Vital Statistics, Hudson County, N. J., has revised its "Rules and Regulations" governing details of fuel-burning equipment required for issuance of permits and certificates.

William G. Christie, member of the Council, A.S.M.E., smoke-abatement engineer of Hudson County, writes that any one wishing a copy of the "Rules and Regulations" may procure one by sending him three cents in stamps at the Court House, Jersey City, N. J.

Aircraft Fasteners Division Formed

THE American Institute of Bolt, Nut, and Rivet Manufacturers has announced the formation of an Aircraft Fasteners Division as a result of the increase in the number of matters relating to aircraft fasteners that have been taken up with the Institute by various persons and organizations.

H. O. McCully, Russell, Burdsall, and Ward Bolt and Nut Company; J. W. Fribley, Cleveland Cap Screw Company; A. M. Jones, Buffalo Bolt Company; and C. F. Newpher, National Screw and Manufacturing Company, constitute a committee to establish the division, with Mr. McCully acting as chairman.

A.S.M.E. Calendar

of Coming Meetings

September 30–October 1, 1943
Joint meeting of the A.S.M.E. with The Engineering Institute of Canada
Toronto, Ontario, Canada

October 28–29, 1943
Joint Meeting of A.S.M.E. Fuels and A.I.M.E. Coal Divisions
Pittsburgh, Pa.

November 29–December 3, 1943
A.S.M.E. Annual Meeting
New York, N. Y.

Joint Fuels Conference to Be Held by the A.S.M.E. and the A.I.M.E.

In Pittsburgh, Pa., October, 28–29

ANNOUNCEMENT has been made of a Joint Fuels Conference of the American Institute of Mining and Metallurgical Engineers and The American Society of Mechanical Engineers to be held at the William Penn Hotel, Pittsburgh, Pa., on October 28 and 29.

A General Committee established by representatives of the two associations consists of T. E. Purcell, Chairman, H. F. Hebley, L. E. F. Wahrenburg, A. W. Thorsen, T. J. Barry, and H. P. Greenwald. The group, already at work to insure the success of this timely and important conference, has appointed several subcommittees headed by the following chairmen:

T. J. Barry, arrangements
Martin A. Mayers, program and papers
M. R. McConnell, inspection trips
J. T. Ryan, Jr., publicity
G. A. Shoemaker, hotel and registration.

E. P. Warner Honored by the Royal Aeronautical Society

THE Institute of the Aeronautical Sciences has announced that E. P. Warner, member A.S.M.E., has been made an honorary fellow of The Royal Aeronautical Society (England). The Royal Aeronautical Society was founded in 1866 and has elected only 17 honorary fellows throughout the seventy-six years of its history. Mr. Warner is the fifth American to receive this honor. The others so honored have been Orville Wright (1908), honorary member A.S.M.E.; J. C. Hunsaker (1920), vice-president A.S.M.E., 1939–1941; Major Lester D. Gardner (1939), associate A.S.M.E.; and T. P. Wright (1941).

Clark and Todd Honored at Stevens

STEVENS Institute of Technology, at a recent graduation ceremony, conferred honorary degrees on two members of The American Society of Mechanical Engineers, Wallace Clark and James Herbert Todd.

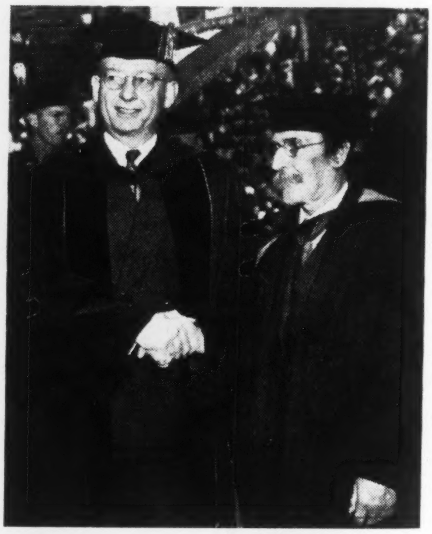
In presenting Mr. Clark for the degree of Doctor of Engineering, President Harvey N. Davis said: "He is a notable example of the international quality of sound engineering and of the world-wide co-operation in constructive endeavor on which alone can a durable peace be based."

Mr. Todd, whose formal education at Stevens was interrupted by World War 1 when he enlisted in the Navy, was presented by Dr. Davis, with the recommendation "that you formally recognize the brilliant function of an education begun at this college by conferring on him the degree of Mechanical Engineer, honoris causa." Mr. Todd is vice-president of the Todd Shipbuilding Company.

S. A. Moss Honored at the University of California

Receives Honorary Degree of Doctor of Laws

AT the Charter Day ceremonies, March 25, 1943, celebrating the 75th Anniversary of the University of California, the honorary degree of doctor of laws was conferred on Dr. Sanford A. Moss, fellow A.S.M.E. In conferring the degree, Robert Gordon Sproul, president of the University, said of Dr. Moss:



ROBERT GORDON SPROUL, LEFT, PRESIDENT OF THE UNIVERSITY OF CALIFORNIA, CONGRATULATES DR. SANFORD A. MOSS UPON WHOM HE HAS JUST CONFERRED THE HONORARY DEGREE OF DOCTOR OF LAWS

"Native of San Francisco, graduate of the University in the class of 1896, and for two years a member of its faculty; able advocate and successful crusader for international standards in science and engineering; consulting engineer to the United States Air Service and recipient jointly with the United States Army Air Corps of the Collier Trophy in Aviation; inventor of superchargers for internal-combustion engines, the basis of airplane flight at very high altitudes; a notable contributor to the efficiency of the air forces of our nation in the war we are now waging."

President's Page

The Engineer at War

IT HAS always been the function of the engineer to eliminate waste and inefficiency. War conditions such as those now prevailing make it more incumbent than ever for the mechanical engineer to utilize his talents to the utmost to design so as to require the minimum of critical materials, the minimum of machining jigs, tools, and fixtures, and processing, and the minimum weight of materials.

Our pressing problem is shipping space. The effective work done in the dehydration of food products has so reduced space requirements for these products as to require fewer bottoms for transport, fewer planes, fewer convoy vessels, fewer guns, less gasoline and oil for the merchant ships' protection, and smaller crews. Engineers have no lesser responsibility to conserve merchant shipping space and the attendant protection equipment through more efficient design and packaging of products for war.

The engineer must also take a responsible part in utilizing waste materials and in salvaging materials. One company alone, the General Electric Company, salvaged 388,300,000 lb of scrap in 1942 for re-use in war production—enough material to fill every car in more than 100 average freight trains. Four fifths of this salvaged material was shipped to steel mills, foundries, and smelters; the remainder was used in the company's operations.

The year's salvage activity yielded 318,500,000 lb of iron, steel, and alloy-steel scrap; 31,200,000 lb of copper, copper-alloy, and brass; 22,700,000 lb of lead; 4,300,000 lb of aluminum; and 2,500,000 lb of zinc. Obsolete tools, fixtures, and other dormant scrap accounted for 25,250,000 lb. Also recovered were 85,300 ounces of silver. Truly, this was an impressive campaign.

We are not all members of General Electric Companies but we can secure proportionate results in our respective spheres.

Through the medium of the War Production Clinics, sponsored by the War Production Board, The American Society of Mechanical Engineers is endeavoring, quite effectively, in my opinion, to bring about an exchange of ideas and to point out how the various problems can be solved or where competent help can be obtained.

The Society also has entered into direct contact with several governmental agencies to solve specific problems presented by these agencies. Obviously, it is not in the public interest to disclose the nature of the projects involved. Suffice it to say that adequate solutions of the problems definitely advance the war effort. Many of you may be called upon to assist in the solution of these problems essential to the furtherance of the war effort.

Many of you may not realize that six of the Society's past-presidents are located in Washington with various governmental agencies: William F. Durand, William L. Batt, Ralph E. Flanders, Warren H. McBryde, Dexter S. Kimball, and Harvey N. Davis. Your Secretary is a colonel attached to the staff of the commanding general of the Army Ordnance Department. Mr. LePage is also devoting two or three days a week of his time to standardization problems arising in the war-production efforts. I am certain that there are hundreds of other members of the Society who are assisting various governmental agencies from time to time.

You have cause to be proud of the efforts that your Society, its officers, its staff, and its members are putting forth.

(*Signed*) HAROLD V. COES, *President, A.S.M.E.*

Among the Local Sections

Successful War Production Meetings Held in Connecticut and California

Governor Baldwin Speaks at Hartford Conference

ON January 21 the War Production and Engineering Council for Northern Connecticut held a conference at the Hotel Bond, Hartford, Conn. It was estimated that between 250 and 300 persons attended. E. L. Milliken of the War Production Board was toastmaster for the evening. Captain A. K. Atkins represented the Navy, and General Drewry and Governor Baldwin spoke at the conference. At the afternoon session F. L. Woodcock, chief tool engineer, United Aircraft Corporation, East Hartford, Conn., was chairman. His subject was "Getting the Most Out of Cutting Tools." Five speakers followed Mr. Woodcock's speech with ten-minute speeches pertaining to tools.

Following this session F. P. Gilligan, secretary, Henry Souther Engineering Company, Hartford, Conn., took over the chair, speaking on "Proper Use and Conservation of Strategic Materials." Six ten-minute talks on this subject followed.

At the evening session F. O. Hoagland, Mem. A.S.M.E., master mechanic, Pratt and Whitney Division, Niles Bement Pond Company, West Hartford, Conn., was the chairman. He spoke on "Product Inspection." Four ten-minute talks were then given. Later, Joseph Barre, Pratt and Whitney Aircraft Division, United Aircraft Corporation, East Hartford, Conn., spoke on "Selection and Training of Personnel for Industry." Six ten-minute talks followed. This War Production Conference was highly successful and the object as set forth by the War Production Board was fulfilled.

Production Clinic Welcomed by Dr. Rufus B. Von Kleinsmid at Southern California

The Southern California Production Clinic was held in Los Angeles on April 30. The address of welcome was made by Dr. Rufus B. Von Kleinsmid, president of the University of Southern California. Lieut. Maurice J. Joyce, chief of production division, western procurement district, of the Army Air Force, spoke on "Army Activity in Aircraft Production."

Watt L. Moreland, district manager of productionservice, the War Production Board, gave a talk on "Engineering Co-Operation in War Production."

Commander J. C. Arnold, U.S.N., office of inspector of naval matériel, discussed "Home Front in Total War." B. C. Coulton, administrative engineer of the Lockheed Aircraft Corporation, talked on "Economic Aspects of Standardization."

Audience of Six Hundred Engineers Attend Panel Sessions

The panel sessions consisted of *manufacturing equipment*, of which J. Roy Hoffman, Mem. A.S.M.E., treasurer, Smith-Booth-Usher Company, was chairman; *welding*, Francis Stevenson, Vega Aircraft Company, chairman; *materials*, E. M. Wagner, consulting engineer, Norris Stamping and Manufacturing Company, chairman; *fabrication*, Robert Milmoe, Lockheed Aircraft Corporation, chairman; C. E. Trimble, Consolidated-Vultee Aircraft Corporation, chairman; Personnel, O. T. Phillips, Douglas Aircraft Company, chairman; *factory electrical equipment*, T. M. Blakeslee, bureau of Power and Light, chairman. Some panel sessions had as many as six hundred in attendance.

Akron-Canton Section Hears Dean Fred E. Ayer

The Akron-Canton A.S.M.E. Section met on April 15. Dean Fred E. Ayer discussed the accomplishments of American universities in training men and women for army and war jobs. The co-speaker was George Marinoff, who presented the paper which he delivered at the Pittsburgh Student Conference where he received second prize.

"Profiting by Experience" at Central Pennsylvania

On May 4 the Central Pennsylvania Section met to hear Dr. A. W. Gauger, director, mineral industries research at Pennsylvania State College, talk on "Profiting by Experience." Dr. Gauger discussed fundamentals and applied research. He stated that one of the functions of applied research is to discover ways of turning fundamental laws, processes, and properties to useful ends. The talk was illustrated by pictures of work carried on by the Mineral Industries Experimental Station. This meeting was held jointly with the Altoona Engineering Society at Altoona, Pa.

Sugar-Beet Industry Discussed at Colorado Section

The Colorado A.S.M.E. Section on April 23 heard E. M. Mervine, U. S. Department of Agriculture, Fort Collins, Colorado, talk on "Recent Developments in the Sugar-Beet Industry." This talk covered the planting of sugar-beet seed, thinning and blocking of plants, pulling and topping of beets, and the many types of machinery developed for this purpose. On May 13 M. F. Blankin, national president of the Society of Heating and Ventilating Engineers spoke before the Section on "An Engineering Society's Effort in Wartime." He spoke at some length on conditions during wartime and the various phases of an engineering-society's efforts.

Columbus Hears Samuel S. Wyer on Plans for World We Want

The Columbus Section held its last meeting for the fiscal year on May 28. Samuel S. Wyer, Mem. A.S.M.E., consulting engineer of Columbus, spoke on "Specifications of the World We Want." The speaker pointed out that isolation for the United States is impossible, that relationships are international, and that, after the war, the people of the world will be no different from what they were before. He suggested a program for the United States to follow which included drawing up some specifications for a postwar world. These specifications included private enterprise with government regulation and a workable substitute for war.

"Target for Tonight" Shown at Detroit Section

The Detroit Section of the A.S M.E. met on May 4. Approximately 150 members and guests were in attendance. Following dinner, a film "Target for Tonight" was shown. This movie gives some appreciation of the tremendous amount of detail work required for each night raid. This Section had as their guests the honorary chairmen and student chairmen of the three Student Branches in the Detroit Section area. A member of the Section Executive Committee who acts as liaison officer between the Detroit Section and the Student Branches made a presentation of a Junior membership to the member of each Student Branch who had won the competition to select the paper to represent the school at the annual spring Student Branch meeting. The speaker of the evening was Lieut. Col. Robert J. Icks, of the Ordnance Department Tank-Automotive Center in Detroit. His topic was "Tanks—Yesterday and Today." Lieut. Icks had a vast background of information on tanks from which to present the complete history of tanks as well as what tanks are doing today.

Detroit Juniors End Season With Ladies' Night

The Detroit Junior Section of the A.S.M.E. held nine meetings during last season and carried on many worth-while activities. New officers were elected for the forthcoming year; V. Russnack, chairman; Charles Gadd, Robert Ferar, Don Jahnke. To wind up their season, 25 members and guests heard Bryant Hall, city-plan analyst, in charge of the Detroit master-plan staff, talk on "Patterns of the Future." Mr. Hall defined purposes of the master-plan activity, sketched a few of the many problems involved, and demonstrated the problems existing in Detroit through land-use maps. He showed some "ideal" solutions propounded by various planners. Included in the points covered in the discussion was the necessity of providing democracy for racial groups other than the majority.

East Tennessee Section Has Two Meetings in May

The East Tennessee Section of the A.S.M.E. met on May 28 when they heard R. D. Lambert discuss "Making Good Hardwood From Inferior Raw Materials." On May 28 this group enjoyed hearing Col. F. M. Gunby speak on "Wartime Industrial Plants" and David Shearer discuss "Engineering After the War."

W. P. Underwood Discusses Hospital Equipment at Erie

On May 12 an audience of 70 members and guests listened to W. B. Underwood, director of research, speak on "Hospital Equipment by the American Sterilizer Company." He gave an interesting demonstration of modern hospital sterilizers and explained the latest processes of sterilization. A film on "Die Casting" by the New Jersey Zinc Company depicted the methods of production of zinc-alloy die castings.

Industrial Postwar Planning at Ithaca Section

On April 30 the Ithaca A.S.M.E. Section held its meeting at which A. E. Marshall spoke on "Industrial Postwar Planning." This was a joint meeting sponsored by A.S.P.E., A.C.S., and S.T.T.S. and participated in by local sections of A.S.M.E., A.S.T.E., A.I.E.E., and A.S.C.E.

Kansas City Hears Captain Elmer Wheeler on "Successful Sizzles"

The Kansas City Section of the A.S.M.E. enjoyed its banquet of May 28 when Capt. Elmer Wheeler of the U. S. Marine Corps spoke on "Successful Sizzles." Captain Wheeler is the originator of the sayings, "Don't Write—Telegraph" and "Say It With Flowers." He gave an interesting and humorous talk explaining practical means of attaining success. The women helped celebrate the finish of a very successful year by joining the group at the banquet. Musical entertainment was also provided.

Col. James L. Walsh Addresses Louisville Section

The Louisville A.S.M.E. Section held a meeting on April 29. Col. James L. Walsh, Mem. A.S.M.E., spoke on "Logistics—the Science of Survival." He described the intricacies of war and urged greater effort by everyone and more engineering ingenuity.

W. W. Fischer, United Air Lines, at Milwaukee Meeting

The A.S.M.E. Milwaukee Section held a meeting on April 14. W. W. Fischer, engineer, United Air Lines, spoke on "Increased Safety Provided by Hi Strength U.A.L. Double Windshield." The speaker discussed methods of simulating bird effects in airplane windshields and described purpose of double-windshield design from the standpoint of weight reduction, ease of defrosting, cleaning, and strength. He also touched on optics of windshields, illustrating common defects found in commercial glass of this type.

North Texas Section Hears About Ammonia by Direct Synthesis

On May 10 the North Texas A.S.M.E. Section heard George E. Kidd of the Magnolia Petroleum Company speak on the topic "Ammonia by Direct Synthesis." He gave a brief history of the development of the process of making ammonia by direct synthesis, also something of the men who did the initial work, followed by a detailed discussion of the process and in particular the design features of the high-pressure equipment used. The talk was illustrated with large drawings of the equipment.

Pittsburgh Section Has Two Successful May Meetings

A joint meeting of the Pittsburgh Section of the A.I.E.E., Electrical and Mechanical Sections of the Engineers Society of Western Pennsylvania, and the Pittsburgh Section of the A.S.M.E. was held on May 11. Two papers were presented. The first was "War Emergency Pipe Line" by H. P. Binder, manager and chief engineer, centrifugal-pump department, Allis-Chalmers Manufacturing Company.

Prior to this paper was shown a colored sound film of the construction of the 24-inch pipe line from Texas to North City, Illinois, entitled "Oil for War." The Pittsburgh Section would recommend this combination of movie and discussion on the "Big Inch" pipe line as a very timely topic with very good presentation by Mr. Binder to any Section interested in the subject.

The second paper for the evening was entitled "Power for the Pipes of War" by H. A. P. Langstaff, electrical engineer, West Penn Power Company. The entire program of the film and two papers gave an excellent birds-eye view of the problems encountered in the several phases of war-emergency pipe-line construction and operation. The meeting was well attended, there being approximately 165 engineers present.

The second meeting, held on May 18, was A.S.M.E. Fellowship Night and was the second effort on the part of the Pittsburgh Section to stimulate better acquaintance among the members as well as to interest Student and Junior members in Society participation. The main speaker was Dr. A. Allen Bates, manager of the chemical and metallurgical departments of the Westinghouse Research Laboratories, on the subject "Materials of the Future." The talk covered possible new uses of known materials.

The Engineer in War and Peace at Raleigh-Piedmont, N. C.

The Raleigh-Piedmont and North Carolina Sections of the A.S.M.E. held a joint dinner meeting on May 7 at the King Cotton Hotel in Greensboro, N. C. Dean Samuel B. Earle, Mem. A.S.M.E., of Clemson College, South Carolina, gave a talk on "The Engineer in War and Peace" with particular reference to the mechanical engineer. Considering transportation difficulties and the scattered membership of the two Sections, the meeting was highly successful.

Sponge Iron Discussed at Rock River Valley Section

On May 18 the Rock River Valley Section heard Dr. C. C. Balke of the Fansteel Metallurgical Corporation, North Chicago, Illinois, speak on "Sponge Iron." Thirty-six persons attended this meeting.

Chromatic Stroboscope and Job Training, Topics at St. Joseph Valley

On May 14 the St. Joseph Valley A.S.M.E. Section held its meeting. Allen Loomis, Mem. A.S.M.E., experimental engineer, C. G. Conn, Ltd., Elkhart, Ind., spoke on "Chromatic Stroboscope" and Howard Young spoke on "Job Training." Mr. Loomis covered its principles and demonstrated the stroboscope for measuring pitch of musical instruments. Mr. Young explained training methods to eliminate lost motion in war-production plants. A film on "The World at War" and two saxophone solos by Mr. Waddington, the Section chairman, were enjoyed.

Prof. R. L. Daugherty Speaks at Southern California

On May 13 Southern California Section held a dinner meeting and heard Prof. R. L. Daugherty, past vice-president and fellow A.S.M.E., discuss "Theoretical Analysis of Real Engine Cycle." Professor Daugherty traced the method of computing the performance of an engine cycle by means of thermodynamic charts, which take into consideration the fuel/air ratio, the chemical composition of the mixture before and after combustion, and the effect of dissociation. He showed also how to compute the temperature next to the spark plug and the temperature and pressure of the last part of the charge to burn (*a*) normally, (*b*) with detonation. Professor Daugherty is head of the mechanical-engineering department of the California Institute of Technology, and regional adviser, engineering defense training, U. S. Office of Education. His address was directed to the very latest developments relating to combustion and carburetion.

Postwar Engineering at Washington, D. C.

On May 13 the final meeting for the season of the Washington, D. C., Section of the A.S.M.E. was held in the auditorium of the Potomac Electric Power Company. The guest speaker was Prof. A. G. Christie, past-president A.S.M.E., of the Johns Hopkins University, whose topic was "Postwar Engineering." The main points of interest brought out in Professor Christie's talk were: first, an expected general increase in the use of lighter metals for the manufacture of equipment; second, new fields of application for plastics; and third, an increased use of air travel making any large expansion of road building of questionable value. Officers were elected for the coming year and presentation of student awards was made.

Present at the meeting were Warren H. McBryde, past-president of the A.S.M.E. and Colonel C. E. Davies, secretary, now on leave, with the U. S. Ordnance Department. Colonel Davies mentioned that the Washington Section is now one of the first ten in size throughout the nation.

Waterbury Section Enjoys Ladies' Night

On May 20 the Waterbury Section heard Mrs. M. E. Dakin of the University of Connecticut speak on "Food Preservation." This was a timely speech covering the entire field of food preservation, and proved of special interest to all present.

High-Pressure Steam Boilers Discussed at West Virginia

The West Virginia Section held its meeting on April 27 when 65 members and their friends were present. New officers were elected for the new year starting May 25. John Van Brunt, Mem. A.S.M.E., vice-president of engineering, Combustion Engineering Company, New York, N. Y., was the speaker of the evening. He spoke on "Design of High-Pressure Steam Boilers and Natural Circulation in Steam Boilers." In his presentation Mr. Van Brunt followed step by step the design of the various elements of a complete boiler which would produce 160,000 lb of steam per hour at 1350 psi pressure and 925 deg F. The talk was illustrated by lantern slides.

With the Student Branches

F. W. Kahl Wins First Prize at University of Illinois Student-Paper Prize Competition

The University of Illinois Branch held its meeting on May 5. Announcement was made of a lecture and demonstration of a Wright cyclone gas engine. The engine (à la Fortress) was on display May 11 and 12. A technicolor film on "Zinc-Alloy Die Casting" by the New Jersey Zinc Company was shown, giving a thorough explanation of the production of castings by the die-casting method. This film was one of the best seen this year by this Branch. On May 19 this Branch met again to hold its last meeting of the year, at which annual student-paper prize competition took place. The winners were, F. L. Kahl, first prize, for his paper on "Creep Properties of Cellulose Acetate;" P. R. Noling, second prize, for his paper on "Development of Hydraulic Governors;" W. J. Gailus, third prize, for his paper on "Fatigue Properties of Paper Laminate."

Paul Salerno Awarded a Biography of W. LeR. Emmet

Paul G. Salerno was awarded a biography of W. LeR. Emmet. This award is given annually to the member who has contributed most to the Branch during the year. Mr. Salerno served as an officer during his junior year, was president during the first semester of his senior year, and twice during the past year has been a speaker on the program of meetings.

On April 5 Alabama Poly Branch enjoyed the film, "The Making and Shaping of Steel," which described the process of making steel from converting ore to final finishing tasks of shaping the steel into girders, wires, and railroad engines. Another film entitled "Steel—Man's Servant" was also shown at this meeting. On April 17 this Branch held a joint dance with M.I.T.E.C. a student co-operative engineering society. Approximately 175 members of both organizations and their friends attended. The dance was semiformal with music by the Auburn Knights. On April 19 this Branch saw a film on "Copper Goes to War," illustrating the many uses for copper in modern warfare. A second film, "From Mine to Consumer " was also shown.

On April 28 the University of California Branch met. Vic Sanders gave a report on the A.S.M.E. Student conference in which several members of the Branch took part. A report was given on the field trip to the Golden Glow Brewery. New officers were elected: Alden Bryant, chairman; Don Bryan, vice-chairman; Dave Kline, secretary; and Austin Sanderson, treasurer. Dr. Hultgren, physical metallurgist from the mining department of the University, then spoke on "The Development of the Magnesium Age and the Methods Used in Extracting This New Metal."

California Tech Branch met on May 10 when films on "Production" were shown. Among problems discussed was the continuation of the group after the Navy program is instituted.

Cooper Union Branch held a joint meeting with A.I.C.E. Student Branch on May 19. Three films from the Bureau of Mines were enjoyed, The Historical Development of Alloy Steels, Zinc Castings, and Nickel Smelting.

Drexel Tech Branch met on May 20 to present newly elected officers to members. The new officers are William Schwartz, president; Warren Zivie, vice-president; William Turner, treasurer; Walter Platt, secretary; and Arthur Watkins, corresponding secretary. Professor K. W. Riddle, Mem. A.S.M.E., of the mechanical-engineering department succeeded Prof. Albert Ripsha as honorary chairman. General Electric motion-picture films were shown on welding.

The Florida Branch held its meeting on May 7. H. N. Ellis spoke on "Sharp Freezing." A. Garavaglia spoke on "Unit Fuel Ejector," and J. L. Cox discussed "The Mining of Pebble Phosphate in Florida."

On April 4 the Iowa State Branch held its meeting. Prof. David L. Arm, Mem. A.S.M.E., reported the meeting at Evanston, Illinois. Two films were shown. One was "The B-26 Bomber" and the other, "The M-3 Tank." This Branch met on April 28 and heard John Baker speak on "A Typewriter for Planograph," which he had presented at the 1943 Midwest Student Branch Conference of the A.S.M.E. at Evanston, Illinois, where he was awarded the second prize. This Branch met again on May 26 and elected new officers for the ensuing year.

The Kentucky Branch met on April 30 when a movie was shown on "Forces Acting on Airfoil." Plans were discussed for an engineers' picnic.

Lehigh Branch held its meeting on February 11. Phil Powers, student, spoke on "Nomograms, Their Theory and Application," explaining the principles and uses of nomograms to the group with diagrams and special circular slide rules.

Textiles Discussed at M.I.T.

On May 13 M.I.T. Branch held its meeting. Professor E. R. Schwarz of M.I.T. gave a lecture concerning the testing of textiles. Slides showing diagrams and photographs of the fabrics and the testing machines were shown and described. He also explained the necessity of textile testing and some of the precautions to be taken to obtain consistent results. New officers were elected.

On May 4 the Michigan College of Mining and Tech Branch held an informal meeting. Members took part in a round-table discussion of the war, engineering's place in the war, the effect upon the plans of the selective service, and chemical warfare.

The Missouri Branch held a meeting on April 12. Plans for the sectional meeting to be held in Kansas City, Mo., April 23, were discussed. Prof. E. S. Gray gave a brief description of previous sectional meetings. He also advised the Branch of the death of Lieut. Alvin Koch in North Africa. Lieutenant Koch was one of last year's graduating A.S.M.E. student members. A motion picture on "Cyclone Combustion," furnished by Curtiss-Wright, was shown.

On May 6 the Montana Branch met to hear Dave Lawlor talk on the "Path of Copper Through Great Falls, Montana." The various stages in processing and electrolytic refining of the copper from ore were described. The members were particularly interested in the mechanical nature of apparatus and machinery used in reduction works. On May 13 this Branch met again. Ed. Kunkle spoke on the subject "Hydraulic Transmissions." He outlined the various types in present use and pointed out their advantages and disadvantages.

At the May 5 meeting of Nebraska Branch new officers were elected. A report was given on the District Student Branch meeting held at Kansas City on April 23. The Nebraska Section of the A.S.M.E. made three awards as follows: Junior A.S.M.E. membership award to Melvin Hartmann; Mark's Handbook, to Howard Walters; "Biography of a Prominent Engineer," to Jack Wagner. A film on "Paratroops" showed some of the steps in the training and conditioning of the Army parachute troops.

On May 24 the NEWARK COLLEGE OF ENGINEERING BRANCH meeting was attended by members of all the engineering societies represented at the college. A discussion of the proposed consolidation of societies which would be in effect for the duration took place but no decision was reached. Five reels of motion pictures were shown depicting Allied armed forces in action.

North Carolina A.S.M.E. Branch Initiates New Members

On May 25 the NORTH CAROLINA STATE BRANCH initiated twelve members into its fold. Each initiate was required to turn in a written report. Penalties were place upon several who did not complete the initiation requirements by sending them through a paddle line. At the end of the ceremony each new member was "baptized" by immersion in the large laboratory water trough. The evening was enjoyed by all—even the initiates.

On April 29 NORTHEASTERN BRANCH held its first meeting of the new year for the election of new officers; William Mitchell, chairman; Robert Beane, vice-chairman; M. E. Ellion, treasurer; and N. Molino, secretary.

War Bond Purchased by Ohio State Branch

The OHIO STATE BRANCH met on April 16 for its third spring-quarter meeting. The guest speaker was Kennan Hanley, the inventor and designer of the water-jet-propelled fire boat. His lecture covered the relative merits of screw- and jet-propelled fire boats. On April 29 this Branch held a combined meeting with the S.A.E. Student Branch. James Smelker moved that a $100 war bond be purchased. Bernard Hatten moved that the bond be inscribed, "O.S.U. Student Branch A.S.M.E." Both motions carried. Papers were given by Ted Czuba on "The Effect of War on Young Engineers;" and Ben Olson on "Welding and Shipbuilding." Mr. Olson was elected as delegate to the National A.S.M.E. contest at Lansing, Michigan.

PRATT INSTITUTE BRANCH at its May 12 meeting witnessed an exceptionally fine sound-color film, "Alloy Die Casting," presented through the courtesy of the New Jersey Zinc Company, which also supplied a 24-page booklet describing the zinc-alloy casting process used by the company. The film and booklet illustrated many important design features that are essential to the engineer designing modern alloy dies and the accompanying casting equipment.

"Wheels Across India" Shown at Swarthmore

On March 25 SWARTHMORE COLLEGE BRANCH saw the movie "Wheels Across India," filmed by the Dennis, Roosevelt Expedition. Of special interest were shots showing the primitive logging operations of the country in which the elephant was the prime mover, as well as scenes depicting huge waterwheels used to irrigate the fields. This Branch met again on May 6. The film "Zinc-Alloy Die Casting" by the New Jersey Zinc Company was shown. This movie explained that die casting can be made with a nice precision. Many examples of precision-cast products were shown in the film, including gears, carburetors, locks, and gasoline pumps. Prof. Philip Potter presented Robert Williams with a book entitled "Robert Henry Thurston," a biography, on behalf of the society for having done the most to further the interests of the A.S.M.E. on the campus during the past year.

MEMBERS OF THE SOUTH DAKOTA STATE COLLEGE STUDENT BRANCH

On February 11 SYRACUSE BRANCH held its regular monthly meeting. After a business meeting, at which plans were made to hold the sectional meeting at Syracuse, two films were shown—"Guarding the Speechways" and "Aladdin's Lamp."

Texas Tech Promotes Fellowship

TEXAS TECHNOLOGICAL BRANCH met on April 5 when Mr. Roberts, a practicing engineer, gave a talk on the "Pantex Ordnance Plant at Amarillo, Texas." Harlan T. Dowell was announced as the most valuable member of this Branch for the last year. Plans were formulated for the coming year and joint meetings with other student societies are to be arranged for the purpose of promoting fellowship among all branches of engineers.

The fourth annual engineers' technological Atelier forum was held at TULANE BRANCH on April 15, the purpose of which is to promote a competitive spirit among students of various departments of the college of engineering. One student from each department delivered a talk on a subject pertaining to his branch of engineering.

VANDERBILT BRANCH at its meeting on March 9 elected new officers, as follows: Earl Salla, president; Campbell McLester, vice-president; Warren Sawyer, secretary; and Jack Hudson, treasurer.

At the May 10 meeting of the VIRGINIA POLYTECHNIC BRANCH faculty members of the department of mechanical engineering of the Institute were in complete charge. Prof. C. H. Long gave a brief résumé of his trip to the Student Convention held at College Park, Maryland, during the week of May 8. Prof. J. B. Jones, Mem. A.S.M.E., and head of the department, told the history of the local mechanical-engineering laboratory. Professor Jones then spoke on "Production and Use of the Propane Cooking Gas by Many of Our Municipalities." This Branch met on May 17 for a smoker in the mechanical laboratory. Students who had attended the convention at College Park, Maryland, gave short résumés of their experiences. A quiz program followed with Professor Jones acting as "Doctor I.Q." Cigarettes were given as prizes.

On May 6 when the WASHINGTON BRANCH of St. Louis, Mo., held its meeting, it was announced that Pete Barrett was to receive the book award given by A.S.M.E. for outstanding work in the organization. Air Cadet Barrett, on furlough, was present to receive his award. This Branch held a final meeting on May 26 with twenty-six members in attendance. New Officers elected were: John B. Bartley, chairman; Richard V. Jackson, vice-chairman; G. Wayne Van Winkle, secretary-treasurer. It has been decided to make copies of the group picture in the April issue of MECHANICAL ENGINEERING available to all student members. A small gift is to be presented to Miss Morrison, secretary to the mechanical-engineering department.

Student Branch Papers at West Virginia

The WEST VIRGINIA BRANCH of the Student A.S.M.E. have held several meetings during April and May. On April 4 this Branch met and the American Society of Mining Engineers showed a film on "Joy Mine Equipment." This Branch again met on April 11 at which they enjoyed listening to Frank Mumma speak on "Glass Gages" and J. J. Jenkins speak on "Diesel Electric Drives for Ships." On April 18 this group heard a speech on "The Future for Engineering Students," by T. E. Purcell, Mem. A.S.M.E., general superintendent of power stations, Duquesne Light Company. On April 25 three papers were presented, "Magnetic Nail Pickers," by R. DeMarco; "Bayonet Manufacture," by J. Murral; "Alternating Current for Naval Vessels," by M. Butcher. On May 3 a member of the A.S.M.E. Student Branch, John Wargacki, gave a lecture before the general society on "Boulder Dam." On May 10 this Branch met again and heard student papers presented on "Secondary Nonferrous Metallurgy," by Jack Murray; "Runway Construction in War," by James Nunley; "Plywood Glue," by Gerald Pase; "Downdraft Coking Furnaces," by William Waseman; "Human Problems in Industry," by Emil Allegrini.

High-Speed Photography

At the May 12 meeting of WORCESTER POLYTECHNIC BRANCH, Victor Speavich, the speaker of the evening, and at present working on secret experiments for the Government, gave a talk, demonstration, and movies on high-speed photography. The talk contained a short history of this subject, and the movies showed the study of the flight of the shuttle of a loom. The film also portrayed the difficulties in the past of taking pictures and how new light techniques have improved conditions.

Twenty A.S.M.E. Student Members Win Awards in Lincoln Contest

E. E. Dreese, Chairman of Jury of Award

TWENTY Student Members of The American Society of Mechanical Engineers have recently received awards in the Engineering Undergraduate Award and Scholarship Program of the James F. Lincoln Arc Welding Foundation.

In all, 77 awards, totaling $5000, were made by the Foundation to students representing 33 colleges and universities. The total of the 7 scholarships won by students for their universities was $1750.

The Engineering Undergraduate Award and Scholarship Program was announced December first last year and closed April first.

E. E. Dreese, Chairman of Jury of Award

Judging of the papers was under the direction of Dr. E. E. Dreese, chairman of the jury of award. Preliminary judging was done by Dr. Dreese assisted by six faculty members of Union College, Schenectady, New York, where the first step of the judging took place. Final judgment was carried out at Buffalo, N. Y., by Dr. Dreese assisted by Robert E. Kinkead, widely known welding consulting engineer, Cleveland; Dr. J. C. Hodge, vice-president, Wellman Engineering Company, Cleveland, who is located at the company's Akron plant; and W. C. Landis, works manager of the Westinghouse Air Brake Company, Pittsburgh, Pa.

The Engineering Undergraduate Program is the third award study project sponsored by the Lincoln Foundation. Its object, as set forth in rules, was "to encourage engineering students to study arc-welded construction so that their imagination, ability, and vision may be given opportunity to extend knowledge of this method and thus aid the war effort and economic reconstruction in the peace which is to follow."

A.S.M.E. Student Members

In addition to Herman J. Brenneke, of New York University (see MECHANICAL ENGINEERING, June, p. 461), who received the first award of $1000 and the additional honor of having four scholarships of $250 each presented in his name to his university's department of mechanical engineering, the A.S.M.E. Student Branch members who won awards were as follows:

MURRAY S. DIPPEL, Newark College of Engineering; HOWARD MCMILLIN, Oklahoma A.&M. College; RICHARD BLISS, CLARKSON College of Technology; ROGERS S. CANNELL, University of Nebraska; MARVIN L. CARTER, JR., Oklahoma A.&M. College; WILLIAM C. SCHMITT, Rensselaer Polytechnic Institute; ANDY J. SHINE, Rensselaer Polytechnic Institute; MILTON KAUFMAN, Oklahoma A.&M. College; ERVIN T. KISSELBURG, Oklahoma A.&M. College; CLAUDE H. MCMILLIN, Oklahoma A.&M. College; ESLEY L. TEDROW, Washington State College; C. W. ENSMINGER, University of Cincinnati; JOHN J. KOTALIK, University of Nebraska; CARL L. METZ, Duke University; WILLIAM L. SCHERIMAN, Oklahoma A.&M. College; ALFRED SCHLEMMER, Oklahoma A.&M. College; WILLIAM W. SHAW, Case School of Applied Science; GEORGE A. WORN, JR., Sibley School of Mechanical Engineering, Cornell University; NEAL COOK, Oklahoma A.&M. College.

Paintings by Student Engineers Shown at Cooper Union

ORIGINAL oil paintings by engineering students at Cooper Union were displayed for two weeks in the library of the Union in an exhibition which opened on May 31, according to an announcement by Prof. Wm. S. Lynch, head of the department of humanities, at the Institute. Professor Lynch sponsors a course on "Approach to the Arts" in which engineers are taught to wield a brush and learn the problems of an artist. The exhibition includes thirty paintings, with subjects ranging from woodland scenes to a P-40 in a cloudless sky. Dean George F. Bateman of the school of engineering, says, "It is not surprising that during these hectic days engineering students should seek to express themselves in graphic arts. How many of us in the last war survived with sanity of mind amid all the destruction and human carnage because we found things of lasting beauty in music, the sculptured form, and the graphic representation of a passing scene."

All the members of the class are fourth-year mechanical-engineering students.

New Welding Library at Ohio State

A NEW library on welding, believed the most extensive in existence, has been established at The Ohio State University, Columbus, Ohio.

Known as the "A. F. Davis Welding Library," it is the gift of A. F. Davis, vice-president and secretary, The Lincoln Electric Company, Cleveland, Ohio. Mr Davis received a degree from the university in 1914 and his reason for placing the library there was the fact that Ohio State has the only four-year course in welding engineering.

Making available for the first time in one place all important literature on welding, the library will be of special value to industrial designers, engineers, technicians, and others interested in research or general information on the various forms of welding and their application to design, construction, manufacture, or maintenance of metal products and structures. Students in the university's course in welding engineering will also find the library of great benefit.

Though in its early stage of development, the library already contains over 700 books. Included are those on metallurgy, designing for welded construction, welding techniques and procedures, properties of weld metals, standard welding handbooks, bound volumes of welding magazines, the award studies of The James F. Lincoln Arc Welding Foundation, patents relating to welding.

The library is located in the Industrial Engineering Building and is under the supervision of J. R. Stitt.

Objectives of Pressed Metal Institute

THE objectives of the Pressed Metal Institute, organized March 17, 1943, by some sixty representatives of sheet and strip metal fabricators, rolling mills, and metal-press manufacturers serving the industry have been announced by George E. Whitlock, president.

The newly organized Institute will cooperate closely with appropriate government departments to speed up and increase mass production of war materials, and it will also engage in research to develop new and extended uses for metal stampings in the postwar period.

In addition to its administrative offices at 19 West 44th St., New York, N. Y., the Institute has established an office at Press Building, 14th and F Streets, N. W., Washington, D. C., so that continuous contact will be maintained with government departments responsible for production of war materials.

George E. Whitlock, president of Mullins Manufacturing Corporation, Warren, Ohio, is president of the Pressed Metal Institute; S. J. Menzel of Motors Metal Manufacturing Company, Detroit, is vice-president; and H. L. Moody of Stevenson, Jordan & Harrison, New York, N. Y., is secretary-treasurer and managing director. The over-all management of the Institute is in the hands of a Board of Trustees.

New American Standards, Transformers, Regulators, and Reactors

THE completion of approved American Standards covering transformers, voltage regulators, and reactors has been announced by the American Standards Association.

The 90-page volume, well-indexed for speedy reference, and profusely illustrated with drawings, charts, and tables, is made up of three parts. The first part includes definitions, standards, and important information relating to the rating, temperature rise, insulation classes, and other performance specifications for induction apparatus, including distribution, power and regulating transformers, reactors, instrument transformers, constant-current transformers, step and induction voltage regulators, current-limiting reactors, and general purpose specialty transformers. The second part consists of the new Test Code for Transformers; and the third part provides Guides for Operation of Transformers and Regulators.

A Correction

On page 431 of the June, 1943, issue of MECHANICAL ENGINEERING in the paper by R. L. Boyer on "Marine-Diesel Auxiliaries" the formula reading

$$L = (d^{5.33}/d_1) \times L_1$$

should read

$$L = (d/d_1)^{5.33} \times L_1$$

(*A.S.M.E. News continued on page 542*)

3" SCH. 40 TUBE-TURN TRADE-MARK .216 WALL
90° Short Radius Elbow
90° Long Radius Elbow
45° Long Radius Elbow
Straight Tee
Reducing Outlet Tee
Concentric Reducer
Eccentric Reducer
180° Long Radius Return
Lap Joint Stub End
Cap
Straight Lateral
45° Shaped Nipple
90° Shaped Nipple
Saddle
Straight Cross
Welding Ring
Blind Flange
Welding Neck Flange
Slip-On Flange
Screwed Flange
Lapped Flange

TUBE-TURN WELDING FITTINGS—RANGE OF SIZES

Type of Fitting	Description	Standard Weight	Extra Strong	Schedule 160	Double Extra Strong	Light Gauge	
						Nominal Pipe Size	Iron Pipe Size
Elbows	90° Long Radius	1/2"-24"	3/4"-24"	1"-14"	1"-8"	4"-24"	3"-12"
Elbows	90° Short Radius	1"-30"	1 1/2"-30"				
Elbows	45° Long Radius	1/2"-30"*	3/4"-30"*	1"-14"	1"-8"	4"-24"	3"-12"
Returns	180° Long Radius	1/2"-24"	1"-24"	1"-14"	3"-8"	4"-24"	3"-12"
Returns	180° Short Radius	1"-30"	1 1/2"-30"				
Returns	180° Extra Long Radius	1"-2 1/2"	1"-2 1/2"				
Tees	Straight	1/2"-24"	1/2"-24"	1"-12"	1"-8"		
Tees	Reducing Outlet	3/4x3/8-24x20	3/4x3/8-24x20	3/4x3/8-12x10	1x3/8-8x6		
Reducers	Concentric & Eccentric	1x3/8-24x20	1x3/8-24x20		1x3/8-8x6		
Caps		3/4"-24"	3/4"-24"		1"-8"		
Stub Ends	Lap Joint	3/4"-24"	3/4"-24"				
Nipples	Shaped, 90° to Header	1 1/4"-12"	1 1/4"-12"				
Nipples	Shaped, 45° to Header	1 1/4"-12"	1 1/4"-12"				
Saddles		2"-24"					
Laterals	Straight	1 1/4"-24"	1 1/4"-24"				
Laterals	Reducing	1 1/4"-24"	1 1/4"-24"				
Crosses	Straight	3/4"-24"	3/4"-24"				
Rings	Welding	3/4"-12"	3/4"-12"				
Sleeves	Welding	2"-24"					

*30" size short radius.

SUPER Tube-Turn 45° long radius elbows, 90° long radius elbows, and 180° long radius returns available in both Standard weight and Extra Strong in sizes from 3" to 12".

Tube-Turn welding fittings and flanges conform to applicable ASA and ASTM Standards. For further details please refer to Tube Turns catalog and data book No. 111.

TUBE-TURN FORGED STEEL FLANGES—RANGE OF SIZES

	150 Lb.	300 Lb.	400 Lb.	600 Lb.	900 Lb.	1500 Lb.	2500 Lb.
Welding Neck	1/2"-24"	1/2"-24"	1/2"-24"†	1/2"-24"	1/2"-24"*	1/2"-24"	1/2"-24"
Slip-On	1/2"-24"	1/2"-24"	1/2"-24"†	1/2"-24"	1/2"-24"*	1/2"-24"	1/2"-24"
Lap Joint	1/2"-24"	1/2"-24"	1/2"-24"†	1/2"-24"	1/2"-24"*	1/2"-24"	1/2"-24"
Threaded	1/2"-24"	1/2"-24"	1/2"-24"†	1/2"-24"	1/2"-24"*	1/2"-24"	1/2"-24"
Blind	1/2"-24"	1/2"-24"	1/2"-24"†	1/2"-24"	1/2"-24"*	1/2"-24"	1/2"-24"
Socket Type	1/4"-24"	1/4"-4"		1/4"-3 1/2"			
Reducing-threaded or slip-on	3/4"-24"	3/4"-24"	3/4"-24"	3/4"-24"	3/4"-24"	3/4"-12"	3/4"-12"
Orifice—threaded		1"-24"	4"-12"	4"-12"	3"-12"	1"-12"	
Orifice—slip-on		1"-24"					
Orifice—welding neck		1"-24"	4"-12"	1"-12"	3"-12"	1"-12"	
Long Welding Neck	1"-24"	1"-24"	1"-10"	1"-10"	1"-10"	1"-10"	

†Dimensions on sizes thru 3 1/2" same as for 600 lb. flanges.
*Dimensions on sizes thru 2 1/2" same as for 1500 lb. flanges.

TUBE-TURN
TRADE-MARK

Welding Fittings and Flanges

The FIRST WELDING FITTINGS 1ST AND STILL THE BEST

TUBE TURNS (INC.) LOUISVILLE, KY. *Branch offices:* New York, Chicago, Philadelphia, Pittsburgh, Cleveland, Dayton, Washington, D. C., Houston, Los Angeles. *Distributors in principal cities.*

Engineering Societies Personnel Service, Inc.

These items are from information furnished by the Engineering Societies Personnel Service, Inc., which is under the joint management of the national societies of Civil, Electrical, Mechanical, and Mining and Metallurgical Engineers. This Service is available to members and is operated on a co-operative, nonprofit basis. In applying for positions advertised by the Service, the applicant agrees, if actually placed in a position through the Service as a result of an advertisement, to pay a placement fee in accordance with the rates as listed by the Service. These rates have been established in order to maintain an efficient, nonprofit personnel service and are available upon request. This also applies to registrants whose notices are placed in these columns. All replies should be addressed to the key numbers indicated and mailed to the New York office. A weekly bulletin of engineering positions open is available to members of the co-operating societies at a subscription of $3 per quarter or $10 per annum, payable in advance.

New York
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Boston, Mass.
4 Park St.

Chicago
211 West Wacker Drive

Detroit
100 Farnsworth Ave.

San Francisco
57 Post Street

MEN AVAILABLE[1]

Mechanical Engineer, master's degree, broad practical shop and technical skill, medium and heavy machinery and machine tools, high-production precision machinery. Mathematical stress analysis, research and development. Good executive experience. Me-804.

General Superintendent, mechanical engineer, with 9 years' experience on design and development, machine shop, foundry, subcontracting of machine parts, and plastics fabrication. Interested in small or medium plant with quality production. Me-805.

Management or Engineering Executive, mechanical or electrical engineer with 27 years' industrial-plant experience, automatic, airplane, rubber, special machinery, nonferrous-metal extrusion and drawing, heat-treating, hydraulic, steam and electric power, construction, chemical, and food products. Prefer South Atlantic or West Coast. Me-806.

Mechanical Engineer, experienced in design and installation of experimental mechanism for aircraft, wishes to move to Pacific Coast. Preference for development work on remote-control equipment or light automatic machines. Background physics and electronic controls. Me-807.

POSITIONS AVAILABLE

Design and Development Engineer with well-rounded experience in machine design. Prefer man with some experience on hemp- or manila-fiber processing machinery, although engineer experienced on similarly constructed machines will qualify. $4000–$4800 year. Washington, D. C., or Chicago. W-2264.

Mechanical Engineer, about 30, mechanically inclined, for product-development laboratory. May be ceramic, chemical, or mechanical engineer. About $3600 year. Ohio. W-2269D.

Industrial Engineer for general work with consulting management organization. Previous experience in time and motion study, production control, process engineering, desired. $5000–$6000 year. Missouri. W-2274.

Tool Designers experienced on jig and fixture work. Should be capable of laying out and carrying job through to completion. Also need mechanical draftsman, preferably one with machine-tool designing experience. Massachusetts. W-2280B.

Industrial Engineers with wide background in management and control of business, rather than one skilled in shop or in technical end of manufacturing field. Should have experience in production control, material control, labor control, inspection methods, standard costs, accounting, office clerical procedure; also experience in field of writing standard practice instructions, i.e., procedures of manuals. To $7500 year. Georgia. W-2289.

Mechanical Engineer with considerable experience in connection with design, manufacture, and application of valves and pipe fittings. Must understand problems of manufacturer as well as user of such equipment. Will be required to study customer problems, write specifications, design special equipment, and do general engineering work in connection with these products. Salary open. Middle West. W-2311CD.

Production Engineer, 38–48, for company manufacturing light machinery. Must know production planning, methods, time study, etc., in connection with machine-tool operations. Salary open. Permanent. New York, N. Y. W-2313.

Training Specialist, preferably graduate, to assist training director in planning and co-ordinating present and postwar training programs of manufacturing company with several years' experience in administering or directing factory training programs. Write, giving complete qualifications. New Jersey. W-2317.

Industrial Engineer familiar with production facilities of Diesel motors, marine engines, machinery of all kinds, and electrical apparatus for both marine and boat equipment. Will be responsible for advising upon allocation of purchasing authority running into large sums annually. Washington, D.C. W-2319.

Production Engineer Must have some tool design, time-study standards, and machine-loading-schedule experience. Will be required to determine type of material from which to manufacture product. Tool design necessary, and operation sequence and equipment. Will supervise design and making of tools. $7500 a year. New York, N. Y. W-2320.

Production Engineer, over 40, graduate mechanical, with experience in production, supervision, control, and costs on automatic machinery. Some knowledge of tools and ceramics helpful. $5000–$10,000 year. Location, northern New Jersey; within commuting distance of New York. W-2346.

Industrial Engineers for work in basic steel-production plant and rolling mill. Should be thoroughly conversant with production planning, wage incentives, methods, maintenance control, labor control, and flexible budgets. Must have steel-plant experience. Permanent. Salary open. Kentucky. W-2349-D1494.

General Plant-Maintenance Engineer, preferably graduate mechanical, with at least 5 years' experience in charge of maintenance, particularly refrigeration, process machinery, electric-motor application, and incidental construction. $4000–$6000 a year. Northern New Jersey. W-2350.

Development Engineers. One electrical and one mechanical. Electrical man should have experience in either radio communications or signal-equipment manufacturing. Mechanical man should be experienced in development and manufacturing of mass production of small mechanical parts. About $4000–$5000 year. Permanent. Connecticut. W-2352.

General Foreman, not over 45, who thor-

(*A.S.M.E. News continued on page 544*)

A.S.A. Issues Its Revised List of American Standards

The American Standards Association today announced publication of its new List of American Standards. More than 600 standards are listed, 94 of which represent new and revised standards approved since the last (August, 1942) issue. These are marked with an asterisk.

Listed by Subject

Standards are listed by subject and cover civil, mechanical, electrical, mining, chemical, and other engineering fields as well as metals and materials, specifications of interest to the textile, wood, pulp, and paper industry, methods of test for the finished product, dimensions, etc. They reach into every important engineering field and serve as a basis for many municipal, state, and federal regulations. By frequent review these standards are kept abreast of new developments in the fields to which they relate.

Special War Standards

A special section of the List is devoted to American War Standards—standards developed specifically for war-production needs. These wartime jobs have been requested by the Army, Navy, W.P.B., O.P.A., and industry. The A.S.A. is now under contract with the Federal Government to carry on such work. Another special section is devoted to American Safety Standards. Four pages of the pamphlet are devoted to an alphabetical listing of standards for easy reference.

This List of American Standards for 1943 will be sent free of charge to anyone writing in for it. Requests should be addressed to the American Standards Association, 29 West 39th Street, New York, N. Y.

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[1] All men listed hold some form of A.S.M.E. membership.

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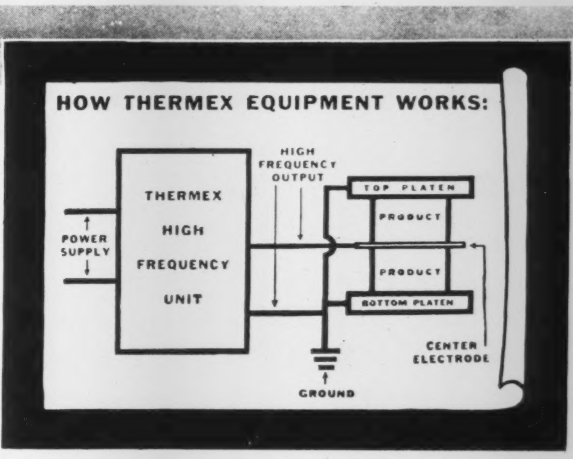

THE advantages of bonding or heat processing non-metallic materials with Thermex high frequency equipment are many. Besides the four advantages above, here are other important reasons why you should consider Thermex equipment for your present bonding or heat processing operations:

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6. Thermex delivers heat at a fixed rate regardless of area or thickness of material.
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